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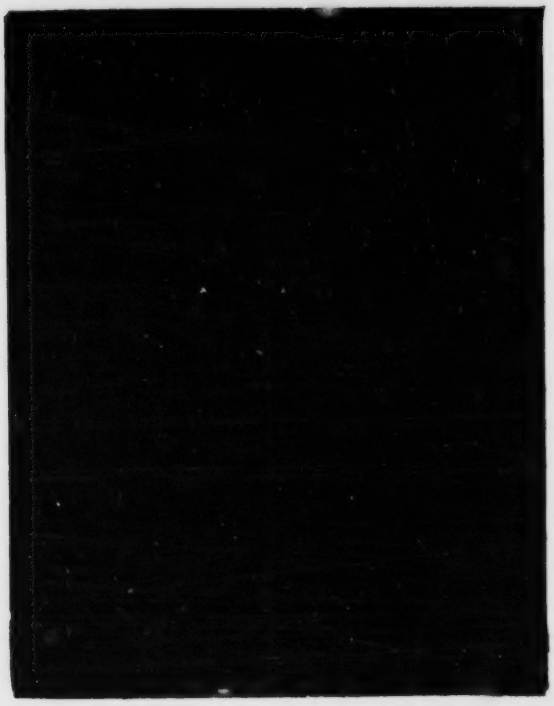

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R&D TRENDS IN THE MINERAL SECTOR IN CANADA

Background Study Prepared for CANMET

Margot J. Wojciechowski

December 1988

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BACKGROUND STUDY

FOR CANMET FINAL REPORT

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Margot J. Wojciechowski
Centre for Resource Studies
Queen's University
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K7L 3N6

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MICROMEDIA

FOREWORD

This is a background study providing input to the final report of a project commissioned by the Canada Centre for Mineral and Energy Technology (CANMET). This background study examines research and development funding trends in Canada in the mineral sector, and is used as a basis for comparison with the corresponding trends in seven OECD countries: Australia, the United States, the United Kingdom, France, the Federal Republic of Germany, Sweden and Finland. Published data sources have been used as far as possible, supplemented by interviews and on-site visits on a limited basis.

The author cautions against the use of R&D statistics as input to policy decisions without taking careful consideration of:

- the reliability of published R&D data, which in many cases is questionable;
- the economic context, impact, and stage in the life cycle of the mineral industries studied, and the jurisdiction in which policy initiatives are being considered.

Simple statistical analysis and manipulation of R&D data will not provide answers to policy questions. Critical evaluation and judgement based on understanding are far more important inputs to the policy process. Data are merely raw materials. It is hoped that this study will provide reasonably reliable data for the raw material needs, and also some understanding of the relationship and dynamics involved in the economics, politics, and technological evolution of the mineral sector.

Views expressed in this report are those of the author, and not necessarily the views of the Centre for Resource Studies and its sponsors, nor of CANMET.

Margot J. Wojciechowski
Centre for Resource Studies

Acknowledgements

The author would like to thank CANMET for initiating and funding this study, and the Canadian Geoscience Council for funding a parallel study in earth science R&D. Doing the two studies in parallel has permitted synergistic benefits to accrue to both. Thanks are also extended to the many people who have been generous with their time and help, in providing information and understanding in the course of research in Canada and in the seven OECD countries which have been surveyed. In addition, a number of individuals have read preliminary drafts of the study, in order to offer comments, corrections and advice. This assistance was essential to the improvements needed in the final report, and is greatly appreciated as well.

The untiring and wise assistance of Holly Linsday, Nathalie Proulx, Kevin O'Grady and Tony Lemprière has been an essential part of the research program for this study. The contribution of Dorothy Smith, Donna Stover, and Sandra Cantelon in keeping up with typing demands has been remarkable, particularly with endless number of tables.

Although grateful for all the advice, information inputs and help, the author accepts responsibility for the opinions expressed and conclusions reached.

SUMMARY: R&D FUNDING TRENDS IN THE MINERAL SECTOR IN CANADA

INTRODUCTION

This study provides information on Canadian expenditure levels and trends in:

- R&D intramural activities of government;
- extramural support by government for mineral-related R&D;
- industry R&D activities;
- education in mining and metallurgy;
- comparisons with other disciplines and other resource sectors.

Where possible R&D effort in mining and the basic metals industry will be presented separately. First, information on the economic impact of the mineral sector in Canada is presented.

THE MINERAL SECTOR:
An Economic Measure of the Importance of Mineral R&D in Canada

In order to understand the economic importance of mineral R&D, it is helpful to examine the role the mineral sector plays in the Canadian economy.

Five key characteristics of the mineral industry in Canada in the period 1980 to 1987 can be identified.

- The combined mining and primary metals industries accounted for an average of about 4 percent of total GDP (2.5 percent by mining, 1.5 percent by primary metals - see figure 1).
- There were wide differences in the importance of the mining industry in the various regions of the country. This was especially true of Quebec, Ontario, British Columbia and the Territories but also of sub-provincial areas. The three provinces all produced a fairly large share of the total value of crude mineral production but have relatively little reliance on the crude mineral industry in their overall provincial economy (see figure 2). The reverse is true of the Territories.

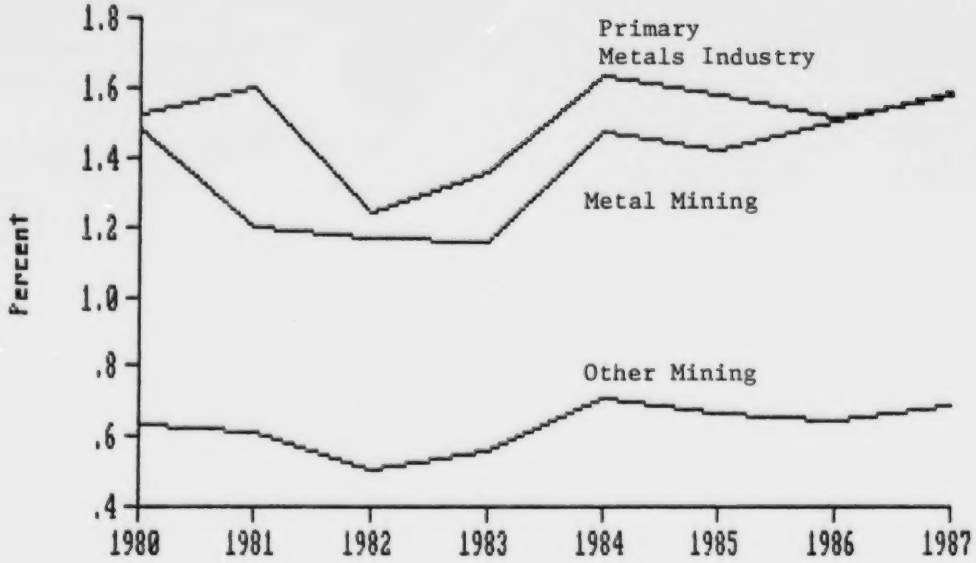

Figure 1 Contribution of the Mineral Sector to GDP, 1980-1987

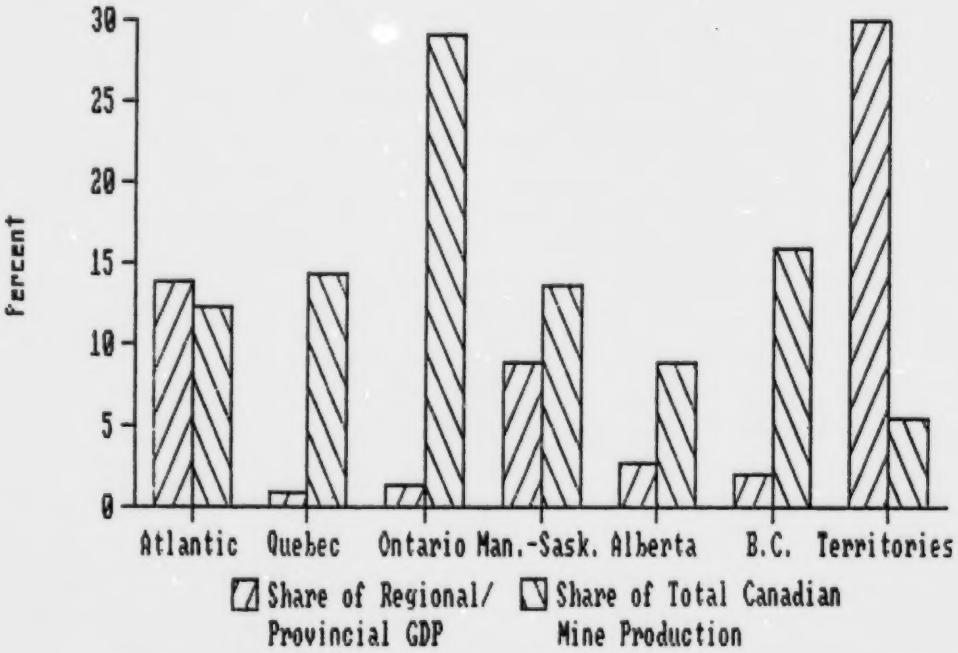

Figure 2 Share of Mining in Regional GDP and in Total Mine Production, 1984

- The combined mining and primary metals industries contributed much less to total employment than they did to GDP, representing an average of about 1 percent of total employment. Substantial reductions have occurred in both industries.
- The mineral industry contributed substantially more to total exports than it did to total GDP, an average of about 15 percent of total exports. Primary metals are somewhat more important than crude minerals. Canada is export dependent for most of its crude mineral production.
- In terms of share in total employment and exports, the relative importance of both the crude mineral and primary metals sectors has declined. The contribution of the latter to GDP has remained fairly steady while the contribution of the former appears to be on the decline.

Some indicators of the importance of the crude mineral industry to Canada are shown in figure 3.

FEDERAL R&D SUPPORT FOR THE MINERAL SECTOR

Overall, the federal government's science and technology (S&T) expenditures rose by 26 percent between 1980/81 and 1987/88, and represented about 4 percent of budgetary expenditures.[1] Federal support for the mineral industry arises largely within the intramural S&T expenditures of Energy, Mines and Resources (EMR). Additional R&D support comes from extramural funding provided by the federal government to provincial governments and industry, but principally to universities via the National Research Council of Canada (NSERC). Federal support for mining and metallurgy R&D is summarized in table 1.

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1. All expenditure figures in chapter three are shown in 1981 constant Canadian dollars deflated using the GDP price index (see appendix table A.2), unless otherwise specified. Percent change is real change based on 1981 dollars. Forecasts are generally given in current dollars because GDP price indices are not available beyond the current year. Multi-year cumulative totals are also given in current dollar terms where no disaggregation by year is available.

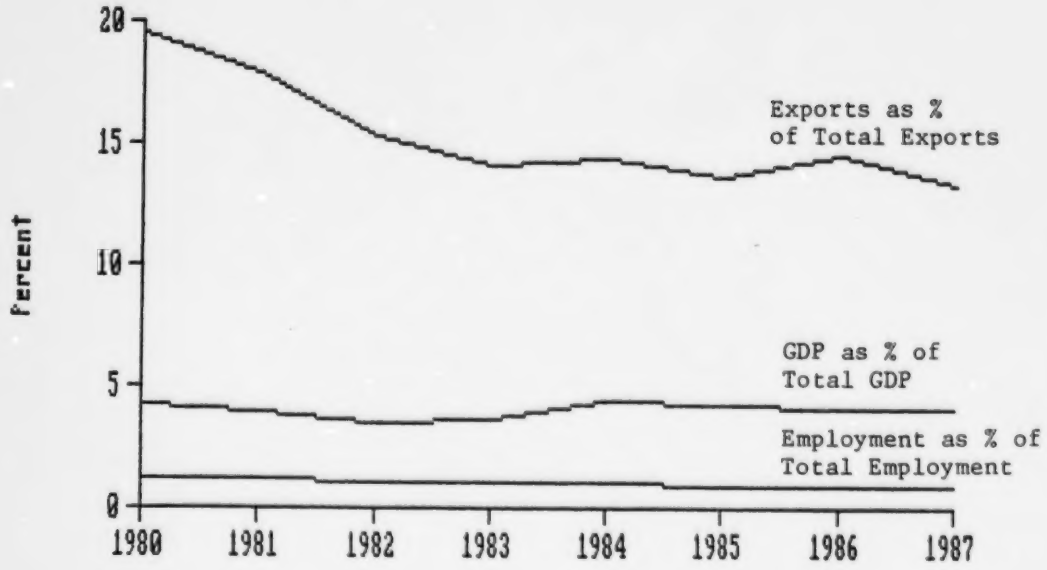

Figure 3 Importance of the Mineral Industry in the Canadian Economy, 1980 - 1987

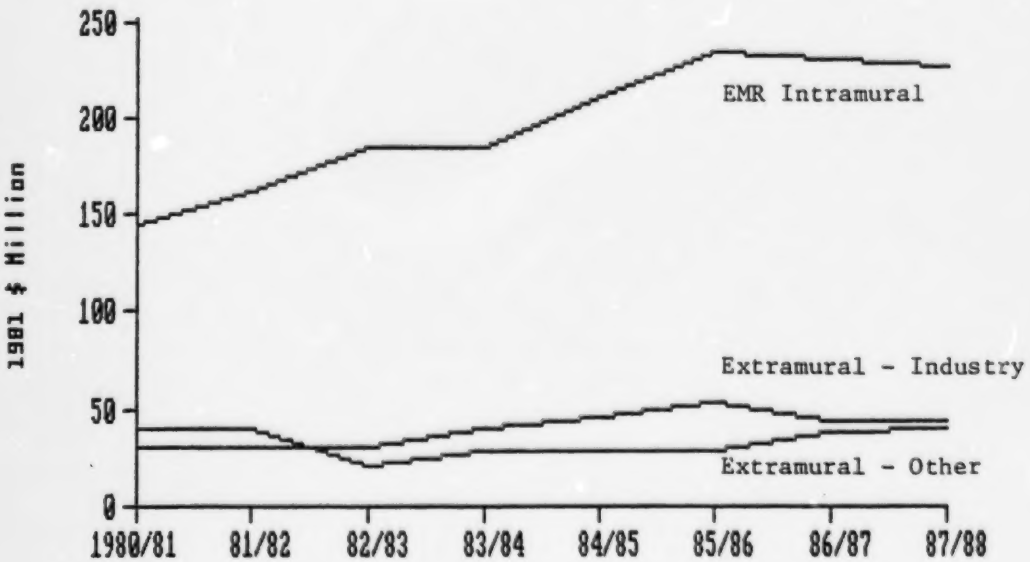

Figure 4 EMR Science and Technology Funding by Recipient, 1980/81 - 1987/88.

Table 1 Summary of Federal Intramural and Extramural R&D Support for Mining and Metallurgy, 1986/87

	1981 $ Thousand	% of Total
Mining		
CANMET	10,436	27.7
of which MDAs	(1,601)	4.2
Quebec MDA	397	1.0
NSERC	163	0.4
EMR grants[a]	127	0.3
Total	11,123	29.5
Metallurgy		
CANMET	21,467	56.9
of which MDAs	(1,894)	5.0
NSERC	5,026	13.3
EMR grants[a]	127	0.3
Total	26,620	70.5
Total mineral industry	37,743	100.0

[a] Total for minerals simply estimated as a 50:50 split between mining and metallurgy.

Intramural Federal Government Funding

Figure 4 shows EMR S&T funding by recipient in the 1980/81 to 1987/88 period. For the most part EMR funding of S&T is intramural (almost 75 percent). The mandate of EMR includes the mining and metallurgy sectors and involves the development and implementation of mineral related policies and programs. The intramural R&D is performed by the Canada Centre for Mineral and Energy Technology (CANMET) which in the fiscal year 1988/89 will spend almost 70 percent of its total budget on R&D; the principal focus of CANMET is on R&D to promote efficiency and competitiveness in the mineral sector.

Unfortunately, disaggregations of CANMET funding by subactivity are not available prior to 1985-86, so that past funding trends cannot be analyzed at this level of detail. Forecasts of future funding levels indicate that CANMET's overall budget will decline by about 12 percent between 1985/86 and 1990/91 in current dollar terms. The decline in terms of the real value of expenditures will of course be even greater. The

A-base, or basic funding used to maintain CANMET's long-term and continuing operations, is expected to remain fairly constant in current dollar terms and hence decline steadily in real dollar terms due to inflation effects.

CANMET's mineral R&D efforts of concern here are undertaken in four activity classifications - mining, coal mining and preparation, mineral processing, and metals and materials. Funding in these areas represented $32 million (1981 dollars) in 1986/87 (see table 1). About one-third of this was in support of mining while the remainder supported metallurgy. In CANMET's mining, mineral, coal, and physical metallurgy research laboratories, A-base funding has remained fairly constant in real dollar terms, at least in the 1985/86 to 1987/88 period.

One significant aspect of the federal government's funding of mining and metals R&D is the series of Mineral Development Agreements (MDAs) undertaken with all provinces and territories except Alberta, generally in a 5-year time frame beginning in 1984 or 1985. The agreements are a combination of extramural and intramural funding, as the federal and provincial governments both provide funds and deliver programs. All of the agreements are meant to strengthen and diversify the mineral sector and each includes a mining and mineral technology component. In total, the MDAs will provide $254 million (current dollars) in the 1984-91 period, of which $31 million will be for mining and mineral technology.

Somewhat more than half of this amount, or $17 million, will be funded by CANMET. Quebec has by far the most ambitious MDA in terms of total funding; the federal funding share is not handled by CANMET, although the funds are provided by EMR. The federal contributions are included in the CANMET totals in table 1, except for Quebec which is shown separately. About $3.5 million of CANMET's total support of $32 million in 1986/87 was in the form of MDA funding, with a 45/55 percent split between mining and metallurgy.

Extramural Federal Government Funding

Federal support for extramural mineral R&D can be divided into two categories: grants for research, mainly to universities and principally through the National Sciences and Engineering Research Council (NSERC) but also through EMR, and contracts for the provision of research and technical services. Support via contracting is often administered on behalf of other departments by the Department of Supply and Services so

that if DSS contracts are included there is a danger of double counting. Hence the second category is covered here only through EMR's expenditure totals noted previously.

NSERC R&D Support for Mining and Metallurgy

NSERC programs are divided into four planning elements: the research base, scholarships and fellowships, targeted research and general support. The research base support provides operating, equipment, infrastructure and special project grants according to distributions determined by discipline-based committees. Targeted research includes strategic grants and university-industry grants. General research support, the fourth element in NSERC's funding program, consists mainly of grants given to university presidents which cannot be classified by discipline as can other grants. In 1986/87 NSERC provided about $5 million in grants for metallurgy research while only about $.2 million was provided for research in mining. Strategic grants reflect to some extent the current or short-term policy thrust and resulting importance assigned to various disciplines. None were reported for mining in the 1980/81-1986/87 period, while such grants represented a fairly substantial proportion of the support for metallurgy. Similarly, no fellowships were reported for mining, while about $70 thousand in fellowship support was given in the metallurgy area. It should be noted, however, that some additional NSERC support for mining-related research is made available under civil engineering discipline code classifications.

EMR Research Grant Support for Mining and Metallurgy

EMR's grant program is concentrated in funding for the earth sciences and energy research rather than mining and minerals and is not large, relative to NSERC funding. Nevertheless, the amount of support going to mining R&D in 1986/87 was equal to the NSERC mining support, while metallurgy NSERC grants were about 40 times the EMR grants for metallurgy, as shown in table 1.

PROVINCIAL GOVERNMENT SUPPORT FOR MINERAL R&D

Despite the fact that minerals represent a significant proportion of GDP in some provinces, there is little in-house mining or mineral-related R&D performed by the provinces. The major exception is Quebec, which has the lowest economic dependence on the mining industry next to Prince

Edward Island (see figure 2) but which nevertheless has a provincial organization devoted entirely to mineral R&D, le Centre de Recherches Minérales (CRM). In addition some in-house provincial R&D on mineral processing is funded by New Brunswick in its Research and Productivity Council (RPC). In Alberta, the Alberta Research Council (ARC) provides mineral-related research funding for various programs emphasizing energy sources and utilization including coal.

Support for mineral R&D in the other provinces is generally small and has been triggered by the Mineral Development Agreements in most cases. Estimates for total provincial mining and metallurgy R&D expenditures for 1986/87 are presented in table 2 These figures understate the full extent of provincial support since it is difficult to estimate the level of non-MDA support, and Statistics Canada does not provide any details of provincial R&D expenditures. It must be noted that 1986/87 was the peak year for MDA expenditures which will drop to almost zero by 1990/91. This may mean a reduction in the already low level of mineral-related R&D funded by the provinces.

Table 2 Summary Estimates of Provincial Mineral-Related R&D Expenditures, 1986/87
(1981 $ thousand)

	Mining	Metallurgy	Total
Newfoundland MDA	0	117	117
PEI MDA	0	0	0
Nova Scotia MDA	0	335	335
New Brunswick MDA	11	35	46
RAC	0	191	191
Quebec MDA[a]	397	0	397
CRM	2,348	2,631	4,979
Ontario MDA	0	0	0
Manitoba MDA	306	257	563
Saskatchewan MDA	0	0	0
Alberta ARC (coal)	1,707	0	1,707
British Columbia MDA	0	0	0
Territories MDA	na	na	na
Total			
MDA	714	744	1,458
Other	4,055	2,822	6,877
Total	4,769	3,566	8,335

[a] Some of this amount may be included in CRM total.

INDUSTRY SUPPORT FOR MINERAL-RELATED R&D

R&D in mining and metallurgy in the private sector in most countries is carried out by 3 principal groups: mining and/or smelting and refining companies; mining and metallurgical equipment manufacturers; and consulting and contracting firms. In Canada, however, there are very few domestic manufacturers of mining and metallurgical equipment. What equipment is manufactured here is largely produced by branch plants of foreign-owned firms which tend to do their R&D in their home-country. The third group, consulting and contracting firms, with very few exceptions do no R&D in Canada. Thus almost all R&D in the Canadian mineral industry is funded and performed by the first group of companies and the following analysis concentrates on these companies.

The Canadian mining industry is fairly concentrated in terms of ownership, with a small group of well-known companies accounting for most of Canada's crude mineral production. These companies tend to be vertically integrated and diversified multinationals. The metal mining sector is highly concentrated with relatively few firms in comparison to the nonmetals mining sector which is characterized by a substantial number of small firms. Foreign control of the mining industry in terms of assets has fallen significantly in the past 2 decades and the core of the industry metal mining shows the least degree of foreign ownership of any of the mining sectors.

The nonferrous smelting and refining sector is dominated by a small number of vertically integrated companies, the same ones that dominate the mining industry. All of these companies possess reserves which have the potential to keep them in the forefront of world mineral production for decades to come. They are also the principal performers and funders of industry R&D in mining and metals.

The ferrous metal mining and processing sector tends to be characterized by a much greater degree of foreign control than the nonferrous sector, but has a similar degree of vertical integration.

Mineral R&D Expenditures by Industry

Figure 5 shows the 1986 levels of overall R&D intensity (current intramural R&D expenditures as percent of sales of R&D performers) for selected Canadian resource-based industries, including mining and metals. The mining and ferrous metal industries are well below the total all-industry average for R&D intensity. The primary nonferrous metal industry does compare favourably, but only due to the inclusion of Alcan

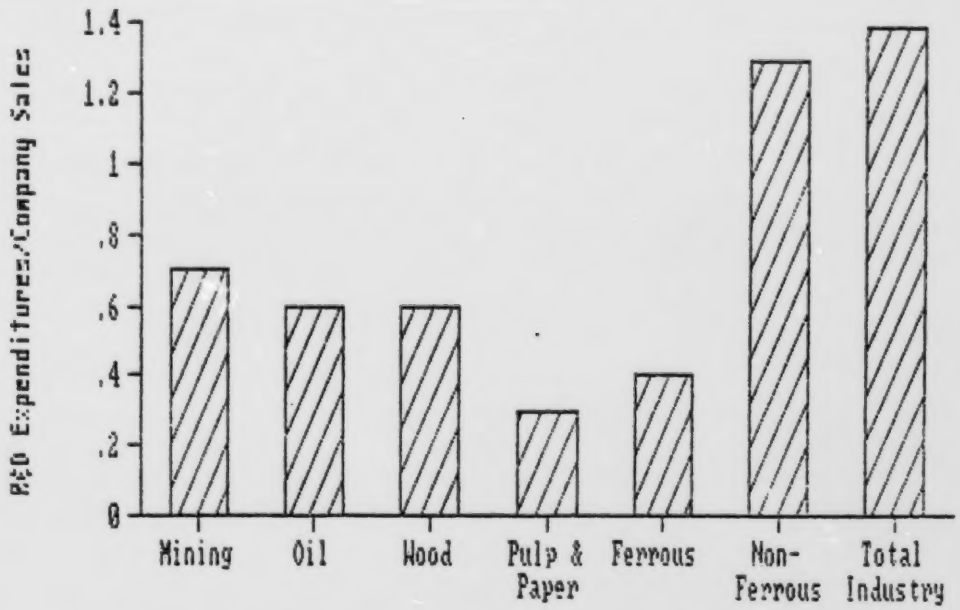

Figure 5 R&D Intensity in Selected Canadian Industries, 1986

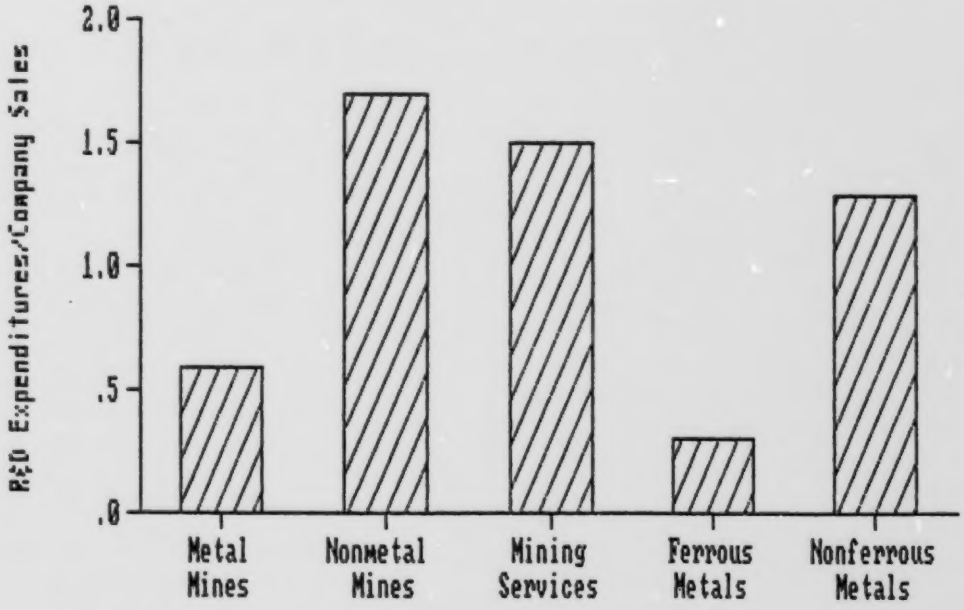

Figure 6 R&D Intensity in the Mineral Industry, 1986

in the category; removal of Alcan figures would probably bring the ratio down from about 1.3 to 0.6. Figure 6 presents R&D intensity figures for various components of the mineral sector. R&D in nonmetal mining and the mining service industries are relatively high but this is a fairly recent phenomenon; in 1979 these ratios were quite low.

It should be noted that these figures represent R&D performed, rather than own expenditures on R&D which are lower, often much lower. In 1986 about 76 percent of total mineral industry intramural mining R&D was paid for with own funds. For ferrous metals the proportion was 100 percent while for nonferrous metals the proportion was 34 percent. Most of the external funding was intracorporate transfers (particularly within Alcan) rather than government support.

Table 3 and figure 7 summarize the available data on mining and metal industry support of R&D. It is immediately obvious that one

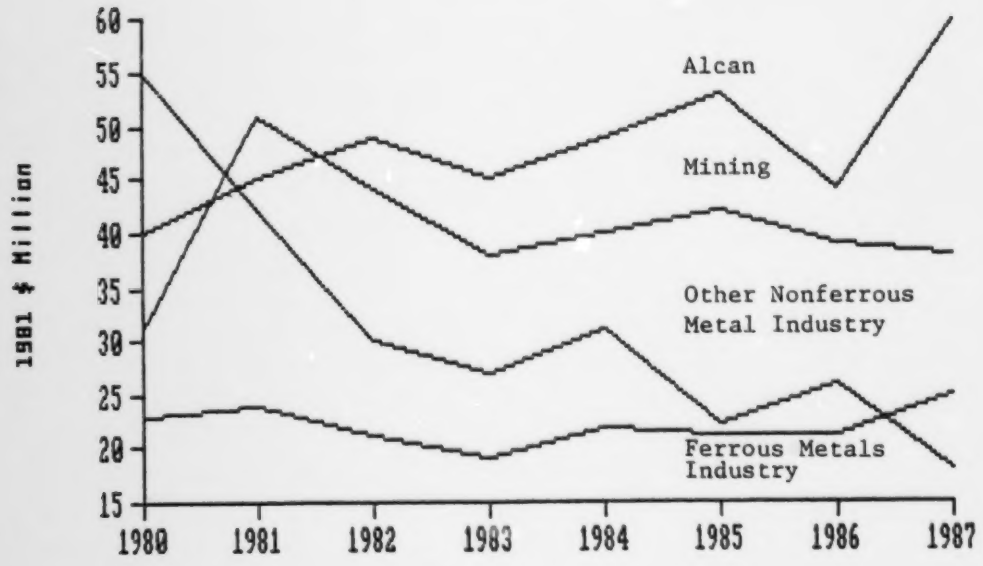

Figure 7 Mining and Metals Industry Intramural R&D Expenditures, 1980-1987

Table 3 Mining and Metals Industry Total Intramural R&D Expenditures, 1979 and 1981-1986 (1981 $ million)

	1979	1981	1982	1983	1984	1985	1986
Mining							
Metallic	22	41	31	25	26	28	25
Nonmetallic	1	6	8	11	11	11	11
Services	-	3	3	3	3	3	2
Mining total	23	50	42	39	40	42	38
Metals							
Ferrous	23	24	22	18	22	21	21
Nonferrous							
Alcan	na	45	49	45	49	53	44
Other	na	42	30	27	31	23	26
Total	72	86	79	72	80	76	70
Nonmetallic mineral products	7	8	7	9	14	14	11

company, Alcan, has been responsible for a substantial proportion of the R&D undertaken by the industry in this decade. In 1986 it represented 63 percent of nonferrous metal R&D and 34 percent of total mining and metals R&D (the 1987 proportions were higher still). Another striking feature is the drastic reduction in "other" (ie. non-Alcan) nonferrous metal R&D. Almost all of the R&D in metal mining and primary metals is done by the few large firms which dominate the industry.

Little concrete data on the division of industry research effort between process and products are available, but some trends have been identified by industry representatives. In nonferrous metals it appears that about three-quarters of the research is in the area of extractive metallurgy and production processes, with the remainder in new product development and materials research. An increasing emphasis on product research is occurring, with Alcan leading the way. In ferrous metal R&D, roughly equal effort is devoted to processes, physical metallurgy and materials properties. R&D expenditures with an environmental focus represent a fairly large part of the effort (about 15-25 percent), particularly within production process R&D in both the ferrous and nonferrous metal sectors.

Industry R&D Organizations

There are no industry research facilities in Canada for conducting joint or collaborative mining or mineral-related R&D. There are, however, a growing number of organizations established to coordinate R&D conducted in-house or by contractors. Cooperative mineral R&D is in the very early stages in Canada, and involves very little actual funding support up to the present time. Most of the influence of these organizations involves identification of targets for existing R&D funding and facilities. However, there are indications that these organizations will be successful in improving communication, in increasing the overall level of funding support and in establishing new centres of excellence, for example around the university chairs that are being established in mineral-related university departments.

Cooperative industry research organizations include the Mining Industry Research Organization (MIROC) with an emphasis on health and safety matters and HDRK Mining Research Limited with a focus on hard rock mining techniques. Organizations which coordinate and promote research include the Canadian Steel Industry Research Association (CSIRA) which coordinates research in all R&D sectors in the technology of steel making; the Mining Industry Technology Council (MITEC) which has as its general goal the improvement of Canadian competitiveness in mining, and the Ontario Mining Association's Mining Research Directorate (MRD) which is primarily interested in rock mechanics and ground control.

EDUCATION TRENDS

Post-secondary education provides Canada with the future researchers who will develop and implement the new ideas needed to maintain industrial competitiveness. Three principal indicators of university education in mining and metallurgy and in all disciplines combined are considered, in order to show trends in human resource potential. These characteristics are university funding sources and levels, the number and rank of faculty, and degrees granted at both the undergraduate and graduate level.

Trends in Overall Canadian Education

Education funding trends can only be considered at the aggregate level, since education is a provincial responsibility and the provinces do not provide information on operating funds by department or discipline. The provinces provide about 80 percent of university general operating income. In total, operating income increased by less than 9 percent between 1980/81 and 1985/86. On a per-student basis, it decreased by 10 percent, and per faculty member it increased by 3 percent over the six-year period. Trends in university operating income relative to GDP, number of faculty, and number of students are shown in figure 8. The number of university teaching staff has increased by about 6 percent in this period, to over 35 thousand in 1985/86. The health sciences have had the largest growth in teaching staff, followed by engineering and applied sciences. In terms of undergraduate enrollment, however, mathematics and the physical sciences have seen the largest increases. The resource sector applied fields have seen a decline in enrollment, as have some branches of engineering, while the humanities, social sciences and biology have grown significantly.

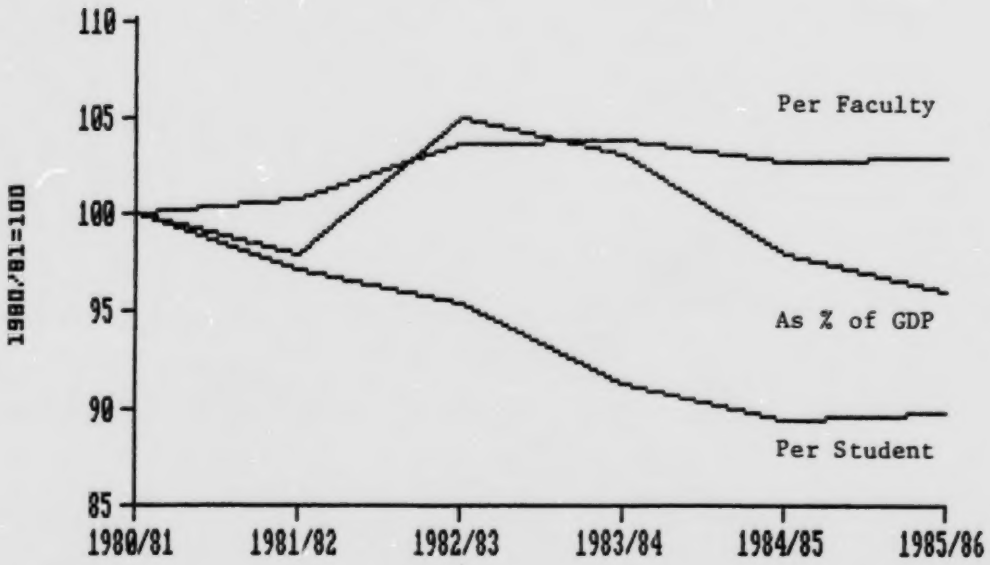

Figure 8 Trends in University Operating Income
1980/81 - 1985/86 (1980/81 = 100)

Education Trends in Mining and Metallurgy

A survey of Canadian universities by CRS indicates that there are 12 universities with mining, mineral engineering, metallurgy or materials science departments. In addition, a number of universities teach mining-related courses in civil engineering departments, and metallurgy and materials-related courses in chemical engineering, chemistry and physics departments. Total mining engineering faculty increased in the 1980-85 period, but there has been no increase in metallurgy and material science teaching staff.

Degrees granted at both the Bachelor and Masters level have increased substantially in metallurgy (see table 4). The same has not been true for mining where undergraduate degrees granted have fallen while the number of Master's degrees granted has been somewhat erratic. The greater interest in metallurgy as opposed to mining is most evident in the number of doctorates awarded. Between 1980 and 1987, 32 PhDs were granted in mining compared to 153 in metallurgy.

Queen's University has had the largest mining engineering department in terms of graduate and undergraduate degrees granted. In metallurgy and metallurgical engineering no one university stands out as a major educator of students.

R&D IN SELECTED SCIENTIFIC DISCIPLINES

Overall R&D in Universities

University research funding represents about 13 percent of total university expenditures and increased by 40 percent between 1980/81 and 1985/86. In comparison, university operating income showed virtually no growth. Almost all university research in Canada is sponsored research, supported by specific grants for specific purposes. Sponsored research income has grown steadily since 1980/81 and its growth is compared to the

Table 4 Indicators of Support for Mining and Metallurgy in Universities, 1980 and 1986

	1980	1986	% Change
Undergraduate degrees granted			
Mining[a]	123	107	-13.0
Metallurgy[b]	83	130	56.6
Total mining and metallurgy	106	237	15.0
Masters degrees granted			
Mining[a]	22	26	18.2
Metallurgy[b]	23	78	239.1
Total mining and metallurgy	45	104	131.1
Doctorate degrees granted			
Mining[a]	3	3	0.0
Metallurgy[b]	15	26	73.3
Total mining and metallurgy	18	29	61.1
Graduate Enrollment[c]			
Mining and metallurgy	193	357	85.0
Total Canada	44,658	54,611	22.3
NSERC grants (1981 $ thousand)[d]			
Mining and metallurgy	2,201	3,805	34.3
Total NSERC	114,171	145,994	27.6
NSERC scholarships and fellowships (number)[e]			
Mining and metallurgy	17	38	123.5
Total NSERC	2,046	3,107	51.9

a Includes mining engineering, mineral dressing and mineral processing.
b Includes metallurgy (arts and science) and metallurgical engineering.
c 1980/81 and 1985/86.
d Research base grants, 1980/81 and 1986/87.
e 1981/82 and 1986/87.

growth of GDP and university operating income in figure 9. The main funding source (about 60 percent) for sponsored research is the federal government. Within the federal government, the major funding source for R&D in natural sciences and engineering is NSERC. NSERC research base peer committee grants to mining and metallurgy increased by 73 percent in the period 1980/81 to 1986/87, well above the 28 percent increase for all disciplines combined (see table 4). This is almost entirely due to metallurgy since mining grants are negligible. In terms of strategic grants, which are flexible in focus and give a sense of the direction government wants research to go, there appears to have been a decline in support for the resource-based disciplines while more high-tech categories have prospered. No strategic grants were given to mining but such grants increased substantially to metallurgy, much more than the overall increase for all disciplines combined.

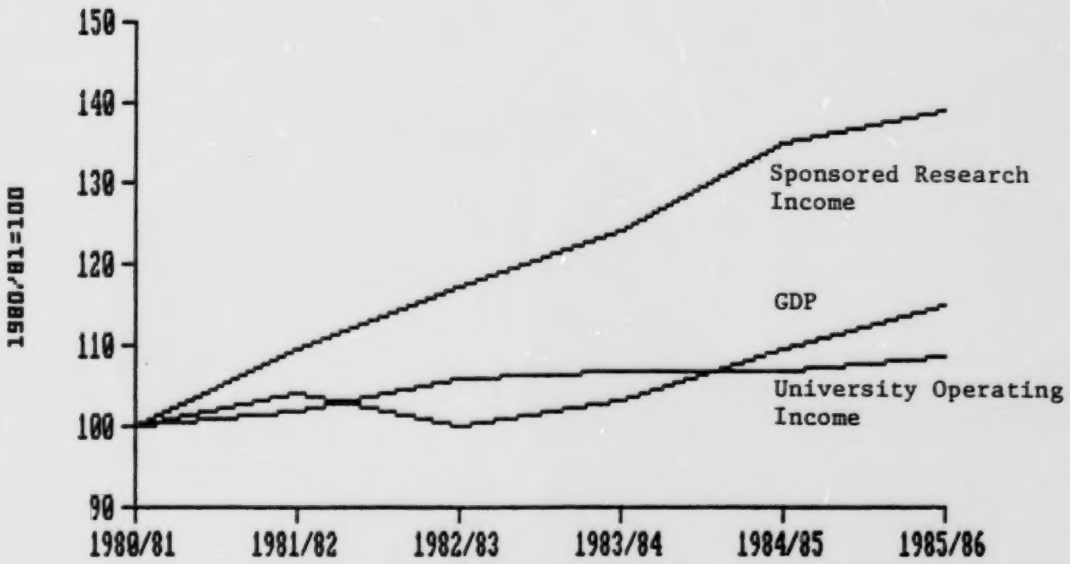

Figure 9 Sponsored Research Income, GDP and University Operating Income, 1980/81-1985/86 (1980/81 = 100)

Total full time graduate enrollment in universities increased by 22 percent in the 1980/81-1985/86 period, while enrollment in the natural sciences and engineering increased by 43 percent. Figure 10 shows trends in total graduate student enrollment while figure 11 shows the distribution of graduate students within the natural sciences and engineering.

Comparison of R&D Trends in Selected Disciplines

Two indicators of trends in university R&D levels and focus are both available and useful: the level of NSERC funding support received by universities, and graduate student enrollment. Table 5 looks at both measures for selected disciplines within the natural sciences and engineering.

In mining and metallurgy, both graduate enrollment and NSERC research base grants have shown much higher increases in this decade than any of the broadly defined natural science and engineering disciplines. Mining and metallurgy combined show approximately 2.5 percent of both total graduate enrollment and total NSERC research base grants. Mining alone, however, had 0.7 percent of graduate enrollment in 1985/86 but received only 0.1 percent of NSERC research base funding in that year.

Table 5 Comparison of Graduate Enrollment and NSERC Grants in Natural Science and Engineering Disciplines

	Graduate Enrollment		NSERC Research Base Grants	
	% of Total 1985/86	% Change 1980/81-1985/86	% of Total 1986/87	% Change 1980/81-1987/88
Biology	16.8	25.3	24.0	29.7
Chemistry	9.3	38.4	12.1	1.0
Physics and space	6.8	37.4	17.9	34.5
Earth sciences	5.9	44.7	7.2	12.1
Math, stats and computing	12.2	66.1	9.3	57.6
Engineering	33.0	59.2	24.7	34.3
of which: mining and metallurgy	2.4	85.0	2.6	72.9[a]
Psychology	16.0	26.0	4.2	33.4
Interdisciplinary	na	na	0.6	12.5
Total	100.0	43.0	100.0	27.6

[a] 1980/81-1986/87.

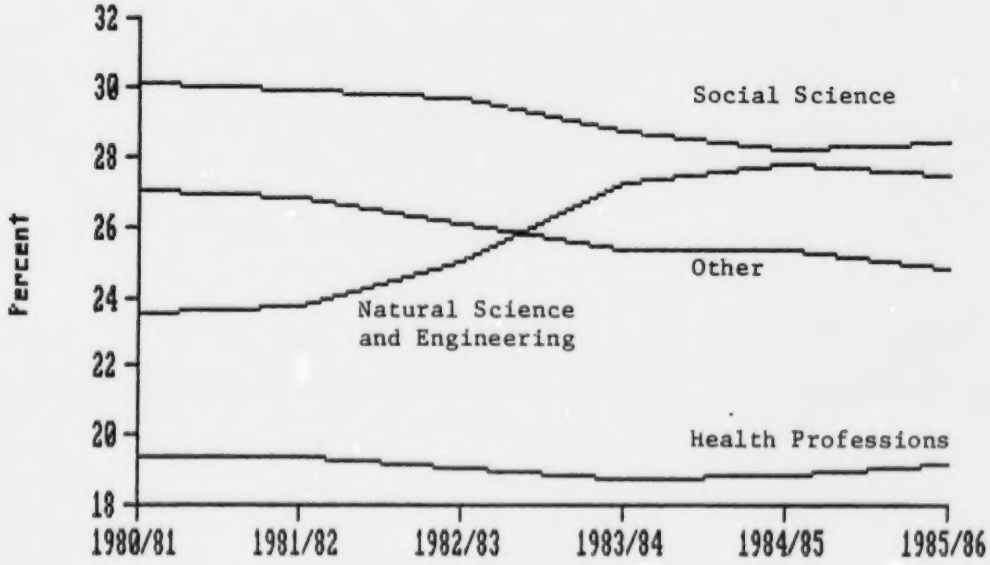

Figure 10 Distribution of Full Time Graduate Students by Field of Study, 1980/81 - 1985/86

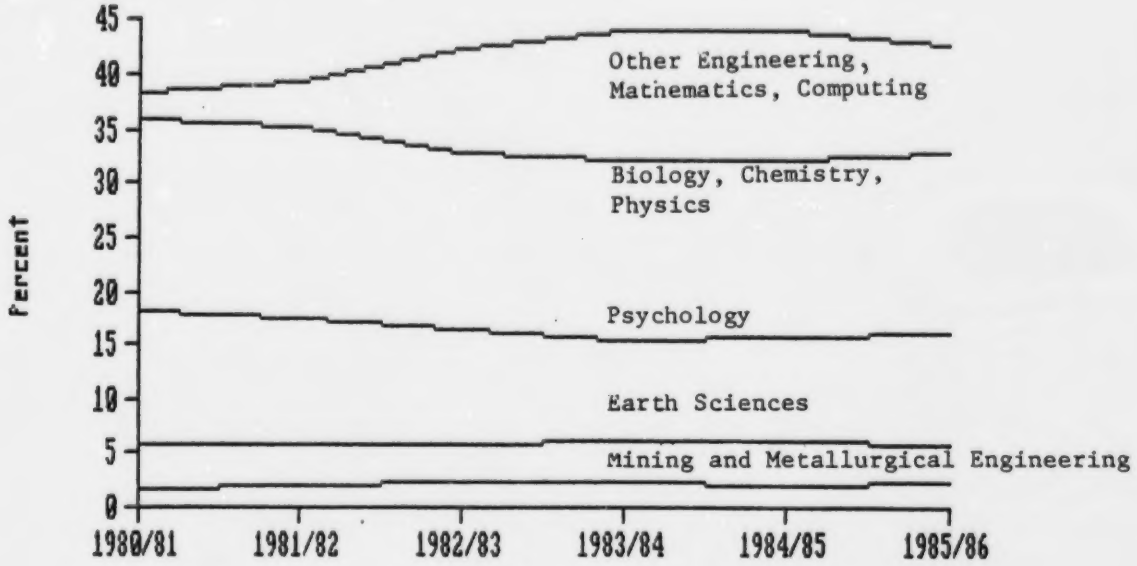

Figure 11 Distribution of Full Time Graduate Students in the Natural Sciences and Engineering, 1980/81 - 1985/86.

Mineral R&D In Universities

The survey of universities conducted by the Centre for Resource Studies provided information on the research funding levels and sources of funds in mining and metallurgical engineering departments. Unfortunately the results are incomplete, as not all departments were able to provide the requested information. The results therefore understate the total level of funding.

R&D grant and contract funding reported by mining and metallurgy departments totalled in the range of $9 million to $10 million per year between 1984 and 1986. About half of the funds were provided by NSERC with other federal sources and provincial governments each providing roughly 15 to 20 percent of the total. Industry contributed between 10 and 15 percent of the funds. It appears that roughly 70 percent of the funding was for research related to metallurgy.

COMPARISON OF R&D EXPENDITURES IN OTHER RESOURCE SECTORS

To put the analysis of mineral R&D into broader perspective, a comparison of R&D expenditures in the various resource sectors in Canada is presented here. The three major resource sectors in Canada are minerals (divided into petroleum and non-petroleum), agriculture (including fisheries) and forestry. Because of the way Statistics Canada data are presented, and to ensure broad comparability across sectors, the crude product, processing and fabricating components of each sector are combined. Unless otherwise indicated, the following analysis deals with the complete sectors.

Economic Contribution of the Resource Sectors

In general, the resource sectors as a whole have decreased their share of total GDP over the past decade from 25 percent in 1975 to just over 17 percent in 1987. This trend is evident in figure 12. Figure 13 shows the contribution of just the crude product component of these sectors to GDP, excluding the processing and fabricating stages. The agricultural sector has contributed the most to GDP in this decade, while forestry has contributed the least. The resource sectors' contribution to exports far outweighs their contribution to GDP, although it is declining. In 1980 they accounted for over 60 percent of exports, but by 1986 this had fallen to slightly more than 45 percent. In terms of employment, the resource sectors show still more variation. In 1985, agriculture provided the most

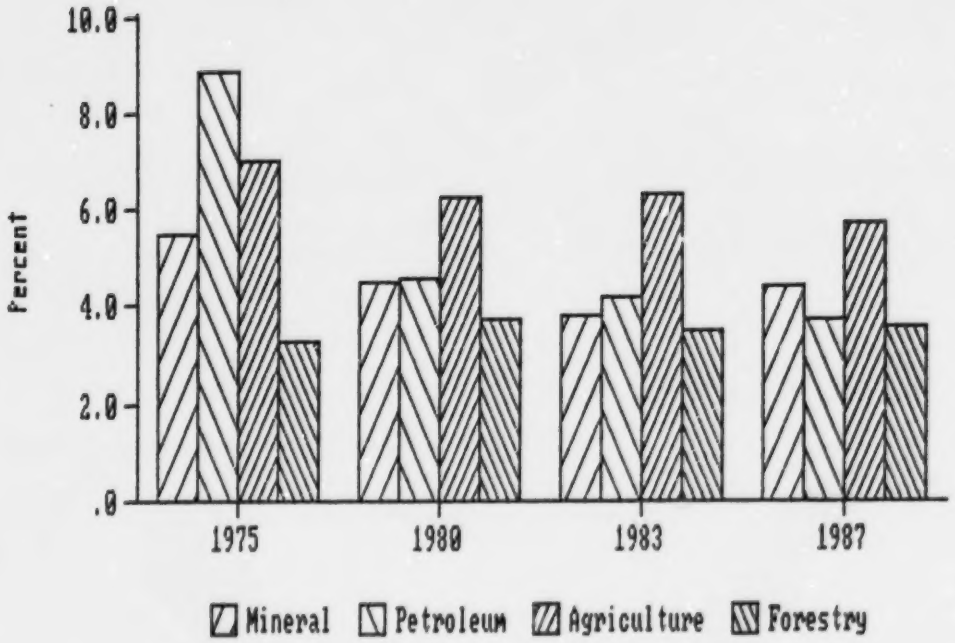

Figure 12 Contribution of the Resource Sectors to Total GDP, Various Years (Sector GDP as % of Total GDP)

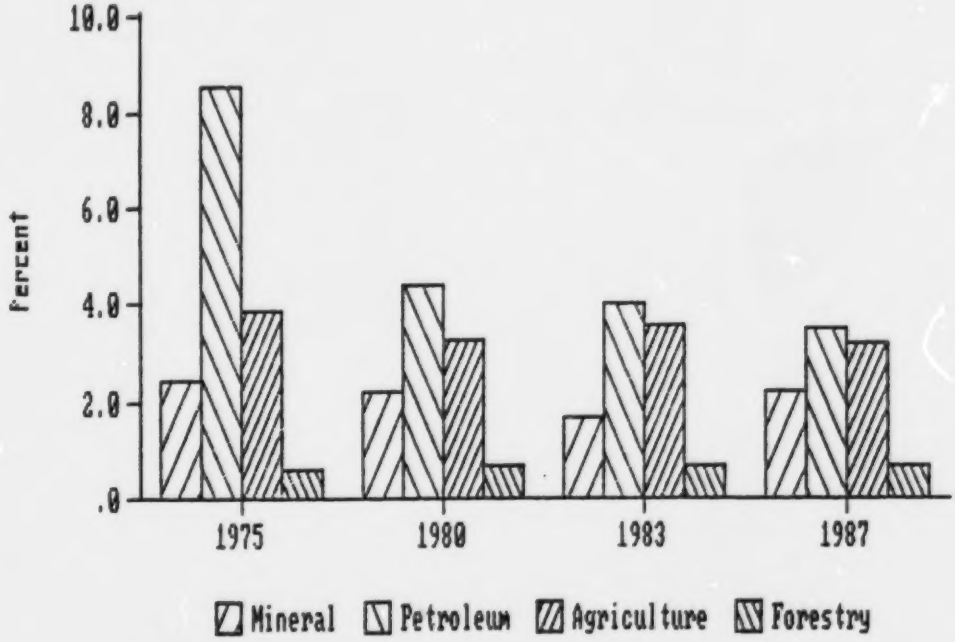

Figure 13 Contribution of the Crude Resource Sectors to Total GDP, Various Years (Crude Resource Sector GDP as % of Total GDP).

jobs by far (with over 700,000 employees). The mineral and forestry industries were approximately equal (250,000 and 268,000 jobs, respectively), while the petroleum industry provided only 86,000 jobs. Some provinces, regions and communities are highly dependent on the resource industries for employment and economic activity.

Overview of Resource Sector R&D

A summary of some of the major funding sources for R&D in the resource sectors is shown in table 6. It is virtually impossible to arrive at firm figures representing the level and intensity of government R&D funding by sector: the data are simply to sparse. The figures in table 6 are not additive and are by no means all-inclusive. They are presented only as an indication of funding sources, levels and trend directions in the various sectors.

Oil and gas exploration expenditures are extremely high in relation to value added, compared to mining expenditures. (This reflects in part the expectation of major petroleum finds, and the relatively low production cost). In R&D expenditures, one conspicuous figure is Agriculture Canada's high level of support for agricultural R&D which is a function of both economic history and the extreme lack of concentration of ownership in the sector. Another is industry support for metals R&D which is largely from Alcan. The R&D intensity numbers (yearly average R&D funding as percent of 1986 GDP, within the relevant part of the sector) should not be cited as absolute indicators of R&D intensity, since the R&D funds are simply averages of crude aggregates over various time periods. They do give some sense of relative intensities.

Comparing the contribution of each sector to total industry R&D and total GDP in 1987 is instructive (see figures 14 and 15 which compare these measures for each sector in its entirety and for the primary component of each sector). Both the mineral and petroleum industries contribute more to total R&D than to GDP. The reverse is true of forestry and agriculture and, although the latter is the most important resource sector in terms of GDP contribution, its industry sector nevertheless makes the smallest contribution to R&D of any resource sector. The ratio of current intramural R&D expenditures as a percent of sales in the resource sectors indicates that they are generally at or below the average industrial R&D intensity for Canada, and well below the levels needed to maintain competitive position in a technologically intensive industry.

Table 6 Summary of Major Resource Sector R&D Funding

Sector	Source	Yearly Average Funding (1981 $ Million)	Percent Change Over Period	Period	Yearly Average As % of 1986 Sector GDP
Earth Science: Geoscience and Exploration	Federal				
	GSC total	61	88	1982/83-1986/87	0.3
	GSC A-base operating	19	-29	1980/81-1986/87	n/a
	Provincial GS				
	Total	48	22	1981/82-1985/86	0.2
	A-base	39	-3	1981/82-1985/86	0.2
	Industry:				
	Mining exploration	474	22	1980-87	6.0
	Oil and gas exploration	3,963	-57	1980-87	30.0
Earth Science: R&D	Federal:				
	GSC	51	86	1982/83-1986/87	0.2
	NSERC total ES	14	36	1980/81-1986/87	0.06
	EMR grants	0.5	-22	1980-87	0.0
	Provincial surveys	21[e]	25[e]		na
	Industry	2[e]	na		na
Minerals	Federal:				
	CANMET[b]				
	Total	61	-12	1985/86-1987/88	0.5
	A-base	34	-19	1985/86-1987/88	0.3
	EMR grants[c]	0.7	-21	1980-87	
	NSERC mining	0.2	na	1980/81-1986/87	0.0
	metallurgy	4	91	1980/81-1986/87	0.1

Table 6 Summary of Major Resource Sector R&D Funding (continued)

Sector	Source	Yearly Average Funding (1981 $ Million)	Percent Change Over Period	Period	Yearly Average As % of 1986 Sector GDP
	Provincial:				
	MDA	3[c]	na	1984-90	0.0
	CRM	6		1980/81-1987/88	0.9[d]
	Alberta (ARC coal)	2	16	1982/83-1987/88	
	Industry:				
	Mining	42	-24	1981-86	0.5
	Metals	99	-32	1981-86	2.4
	Nonmetallic	11	38	1981-86	0.6
Petroleum (primary)	Federal:	na	na		na
	Provincial:	na	na		na
	Industry	69	-46	1980-87	0.5
Agriculture (primary and processing)	Federal:				
	Agriculture Canada[f]	236	63	1980/81-1986/87	3.9
	Agriculture minus Forestry	na	na		3.0[e]
	Federal/prov. agreements[g]	11	na	1982-90	0.2
	Provincial				
	Ont.-ARI[h]	26	-1	1981/82-1986/87	na
	Quebec	15	110	1980/81-1986/87	na
	Industry	63	8	1980-87	1.0

Table 6 Summary of Major Resource Sector R&D Funding (continued)

Sector	Source	Yearly Average Funding (1981 $ Million)	Percent Change Over Period	Period	Yearly Average As % of 1986 Sector GDP
Forestry (primary and processing)	Federal				
	CFS[i]	57	23	1984/85-1986/87	0.9
	PRUF[j]	2	na	1985	
	Forest Dev. Agreements[k]	na	na		na
	Provincial	na	na		
	Industry	15	0	1980-87	0.2
	PPRI[l]	13	9	1980-87	0.2

Note: Funding levels and time periods are determined by data availability.
[e] Author's estimate.

[a] Sector GDP for Earth Sciences is taken as primary minerals plus primary petroleum.
[b] CANMET'S mineral technology expenditures, taken as 100% R&D for this table
[c] Minerals and energy.
[d] $6 million as percent of Quebec 1984 mining GDP.
[g] Included in Agriculture Canada above. Current $.
[h] ARI - Agricultural Research Institute.
[i] CFS - Canadian Forestry Service.
[j] PRUF - Program of Research by Universities in Forestry.
[k] Forestry Development Agreements included very little for R&D. Total funding 1982-90 is federal $421 million and provincial $406 million current, mainly for forest management.
[l] PPRI - Pulp and Paper Research Institute (joint industry and government funding).

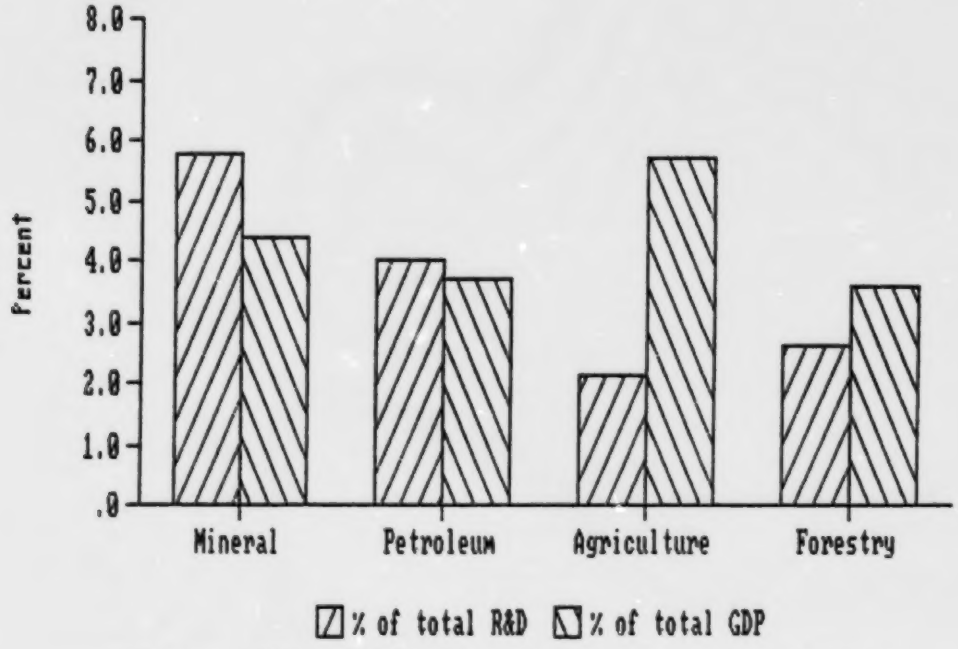

Figure 14 · Contribution of the Resource Sectors to Total GDP and Total Industry R&D, 1987

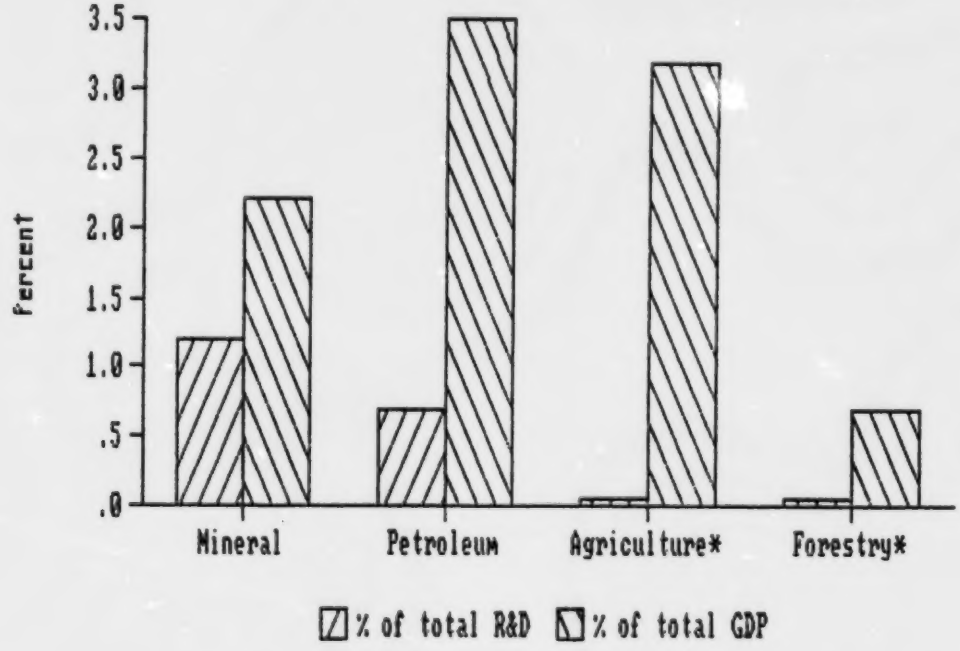

Figure 15 Contribution of the Primary Resource Sectors to Total GDP and Total Industry R&D, 1987

* R&D values unknown but very small according to Statistics Canada, 88-202.

Sector-Specific R&D Data

R&D in the Earth Sciences

Earth science R&D, geoscience activities and exploration are essential in the development and maintenance of the ability to find mineral deposits for both the mining and the oil and gas industries. Most earth science R&D and geoscience is undertaken in the Geological Survey of Canada (GSC) and the various provincial geological survey organizations. GSC total geoscience and exploration expenditures averaged $61 million per year in the 1982/83-1986/87 period and increased substantially. However, long-term support in terms of A-base operating funds (as opposed to temporary add-on funding programs) actually has declined fairly steadily and is projected to keep on doing so. A large part of GSC support for the earth sciences comes from its funding of the federal geoscience component of the MDAs, which is temporary funding.

Provincial earth science activities have averaged about $48 million in the 1981/81 to 1985/86 period. Provincial A-base expenditures in this area have also declined, though not to the same extent as the federal A-base. Together these declines seem to indicate a lessening commitment on the part of government to earth science research. Industry undertakes virtually no earth-science-related R&D, although its exploration programs put a great deal of geoscience data into the public domain.

Research in the Mineral Sector

This sector is covered in detail earlier in this summary.

Research in the Petroleum Industry

Data on oil and gas industry R&D activities related to the combined category of exploration and production are compiled from survey information collected by the Petroleum Monitoring Agency (PMA). The survey represents about 90 percent of the industry and indicates that R&D peaked in 1981 and henceforth declined with a slight resurgence in 1985 followed by a substatial fall in 1986. The sharp fall in 1986 was due to the price drop in oil during that year and was accentuated by the 50 percent decline in federal support for the industry.

Statistics Canada reports substantially lower figures for crude petroleum and natural gas industry R&D expenditures than those derived by PMA but the pattern of expenditures is the same.

Research in Agriculture

Federal research in agriculture is largely intramural, based in the Research Branch of Agriculture Canada. The department's S&T expenditures represent about 25 percent of total expenditures and of this over 85 percent is R&D ($273 million in 1987/88). Extramural support for research in industry and universities is very small, amounting to only a few percent of its total R&D expenditures. Subsidiary federal-provincial agreements for agriculture and food development administered under the Economic and Regional Development Agreements have been signed by six provinces, with two others in the process of reaching an agreement. These agreements include funding for a substantial component of applied research in agriculture (about $90 million current dollars in the 1982-1990 period).

It is generally quite difficult to obtain data on provincial and industrial research expenditures in agriculture. Only Ontario and Quebec have easily identifiable expenditure programs. Ontario funds agricultural research through the Agricultural Research Institute of Ontario which had a fairly stable average budget of $26 million per year in the 1981/82 to 1986/87 period. Over half of this budget covers a contract agreement with the University of Guelph. In Quebec the R&D budget appropriations of Agriculture, Pêcheries et Alimentation Quebec have more than doubled between 1980/81 and 1986/87 and have averaged $14 million per year.

Research in Forestry

Federal activity in forestry R&D is undertaken by the Canadian Forestry Service (CFS), which also administers a program of grants to universities for forestry research. Since 1983, the CFS has been part of Agriculture Canada. CSF total expenditures increased from $53.5 million in 1980/81 to $232 million in 1986/87. Research expenditures from 1984/85 to 1986/87 averaged $57 million per year, and increased by 23 percent over the 3-year period. Federal-provincial Forest Development Agreements have been signed with eight of the provinces but these are directed more at forest management than at research. The forest industry is unique among the resource industries in having its own cooperative research organization, the Pulp and Paper Research Institute of Canada (PAPRICAN), a joint venture of the federal government, McGill University, the University of British Columbia and the Canadian Pulp and Paper Association. PAPRICAN spent an average of about $14.5 million per year between 1980 and 1986.

CONCLUSION

Mineral research and development is a vital component of the effort to maintain or improve mineral sector competitiveness and to search for new markets for mineral products. The mineral sector, and especially mining, has become less significant in the overall Canadian economy, but it nevertheless still retains an important role. It plays a substantial role in Canadian exports and, although it represents a minor proportion of total employment, it is a major source of jobs in certain areas.

The mineral industry is in its mature phase. Canada has good mineral potential, along with the technological ability to develop it. However, in recent years demand changes, price declines, and increased competition from other world suppliers have adversely affected the industry. In such an environment R&D is crucial to maintain competitive position and to realize the industry's long-term potential.

Both business and governments contribute to the R&D effort in mining and metals in Canada (see tables 1, 2 and 3). In 1986 government and industry together spent about $47 million on mining, which represented about 0.5 percent of the 1986 mining GDP of $9,465 million. The federal government spent roughly $11 million, the provincial governments spent $5 billion and business spent about $31 million of its own funds. R&D actually performed by business was higher than its funding contribution, at about $39 million.

In metals-related R&D the government and business sectors spent approximately $75 million in 1986 or 1.4 percent of primary metal GDP of $5,537 million in 1986. The largest portion came from industry ($45 million of its own resources) while the federal government contributed about $27 million and the provincial governments spent about $4 million. Business performance of metals-related R&D was $91 million, much of which came from Alcan.

Part of the total government spending on mining and metallurgy R&D in 1986 was derived from the MDAs - roughly $5.4 million of the total of $46 million. The MDAs will expire in 1990/91 and appear to represent the major mining and mineral R&D effort in many provinces.

It should be noted that the above estimates of R&D contribution are approximate. The actual total funding levels are higher. For example, much of the difference between business R&D expenditures and performance represents funds provided not by the federal governments but by other Canadian sources and foreign sources, including intracorporate transfers. In the primary metals sector funding from these two sources of $45 million accounted for about half of the R&D expenditures in industry (much of this funding was from Alcan International). Some of this funding may be

derived from provincial governments so some double counting may occur but, when added to government and business own expenditures, metals-related R&D totals $120 million or 2.2 percent of primary metal GDP.

Overall funding levels of R&D are one important indicator of the importance attached to mining and metals-related research. Another is the focus of university research and teaching. It is in universities that much of the fundamental research is done, and it is also in universities that the future researchers and innovators will be found. In general it appears that metallurgy is faring better than average, although mining receives very little R&D suport and fewer graduate students. Growth in graduate student enrollment, NSERC grants and NSERC scholarships and fellowships was higher over the period 1980-87 in the combined category of mining and metallurgy than in all disciplines combined.

The focus of government R&D has in general shifted away from the resource sectors. However, some resource sectors do better than others. Agriculture does relatively best in terms of government R&D support with the highest intensity in terms of sector GDP, and fastest rate of increase. All the primary resource industries spend under 1 percent of sales on R&D; in most cases, under 0.5 percent. The mineral industries undertake a fair amount of intramural research (primarily in metals rather than mining). The petroleum industry has cut its R&D expenditures back sharply, and the forestry industry has held steady, at about the same level of R&D intensity as the mineral sector. Industrial R&D as a percent of GDP in all the resource sectors remains below the industrial average and is too low to support major technological innovation.

In summary, it appears that metals-related R&D is fairly strong although much of it depends on the effort of one company. Support in universities also appears to be reasonably strong. The situation is less favourable in mining where the total R&D intensity is much less and university R&D funding is weak.

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Symbols

The following symbols are used in this report:

na	figures not available
-	nil or zero
p	preliminary figures
r	revised figures
x	confidential information
f	forecast
e	estimated (author's estimates are identified as such)
n/a	not applicable

Note:

Some table cells may not sum to the totals shown because of rounding. Nominal figures have been deflated by the GDP implicit price index, 1981 = 100 (see appendix table A.2).

Acronyms

AECL	Atomic Energy of Canada Limited
ARC	Alberta Research Council
AOSTRA	Alberta Oil Sands Technology Research Association
BC	British Columbia
BERD	Business enterprise R&D expenditures
CANMET	Canada Centre for Mineral and Energy Technology
CANSIM	Canadian Socio-Economic Information Mini Base
CCCESD	Canadian Council of Chairmen of Earth Science Departments
CERL	CANMET Energy Research Laboratory
CGS	Canadian Geoscience Council
CIDA	Canadian International Development Agency
CIM	Canadian Institute of Mining and Metallurgy
COGLA	Canadian Oil and Gas Administration
CRL	Coal Research Laboratory
CRM	Centre de Recherches Minerales
CRS	Centre for Resource Studies
DIAND	Ministry of Indian Affairs and Northern Development
DRIE	Department of Regional Industrial Expansion
DSS	Department of Supply and Services
EMR	Department of Energy, Mines and Resources
ERDA	Economic and Regional Development Agreements
F&O	Department of Fisheries and Oceans
FTE	Full time equivalent
GERD	Gross expenditures on research and development
GDP	Gross Domestic Product
GSC	Geological Survey of Canada
IDRC	International Development Research Corporation
ITC	Department of Industry, Trade and Commerce
M&MT	Mining and Mineral Technology (MDA component)
MIROC	Mining Industry Research Organization
MITEC	Mining Industry Technology Council
MOSST	Ministry of State for Science and Technology

MDA	Mineral Development Agreement
MRC	Medical Research Council
MRD	Mining Research Directorate
MRL	Mining Research Laboratory
MSERD	Ministry of State for Economic and Regional Development
NSERC	Natural Science and Engineering Research Council
MSL	Mineral Science Laboratory
NRC	National Research Council
NWT	Northwest Territories
OECD	Organization for Economic Cooperation and Development
OMA	Ontario Mining Association
OMT	Ontario Ministry of Transportation
ORF	Ontario Research Foundation
PCIAC	Petro-Canada International Assistance Corporation
PGJ	Provincial Geologists Journal
PMA	Petroleum Monitoring Agency
PMRL	Physical Metallurgy Research Laboratory
R&D	Research and development
RIE	Regional Industrial Expansion
RPC	Research and Productivity Council (New Brunswick)
RSA	Related scientific activities
SIC	Standard Industrial Classification
SRI	Sponsored research income
SSHRC	Social Sciences and Humanities Research Council
S&T	Science and Technology
UNESCO	United Nations Educational Scientific and Cultural Organization

1. INTRODUCTION

PURPOSE OF THE STUDY

- to provide information on trends in the level, sources and focus of research and development funding in the mineral sector in Canada;

- to set this information in context by providing information on the role of the mineral industry in the Canadian economy;

- to provide information on trends in education in mining and metallurgy in Canada;

- to provide a basis for comparison of education and R&D trends for mining and metallurgy in Canada with those of other disciplines;

- to provide a basis for comparison of the mineral sector and its R&D with other resource sectors in Canada.

DEFINITIONS AND SCOPE OF THE STUDY

The mineral industry for the purposes of this study includes the extraction of crude minerals and their processing into primary products, either metals or nonmetallic mineral products. Processing includes smelting, refining, casting, rolling and extruding of nonferrous metals (including aluminum), iron and steel foundries, pipes, tubes, and other primary steel production. Non-metallic mineral products are chiefly clay and structural products, glass, abrasives, and refractories, and do not include coal products. Physical metallurgy is included as well, in some of the data series in this study, simply because it is often difficult to separate it out from extractive metallurgy. The general intention, however, is to omit physical metallurgy from the study, largely because of the problem of isolating data on metallic materials from the category of materials research, which is increasingly where physical metallurgy data are found. The companies engaged in the activities covered in this study are classified under the Statistics Canada Standard Industrial Classification (SIC) codes which are shown in table 8.1.

Minerals for the purpose of this study are metallic minerals, and nonmetallics including coal, industrial minerals and structural materials. Oil and gas are not included.

For this purposes of this study, **R&D** is defined as "creative work undertaken on a systematic basis to increase the stock of knowledge, including knowledge of man, culture, and society, and the use of this stock of knowledge to devise new applications".[1] For consistency, and to facilitate international comparisons, this study tries to conform, as far as possible, to this Statistics Canada/OECD definition of R&D. Essentially, this approach distinguishes between science and technology (S&T) activities and its subset, R&D. The broader S&T category is composed of R&D and RSA, the latter being related scientific activities which include education and training, other related S&T activities, and other industrial activities. In applying these definitions, Statistics Canada collects and publishes data using the following categories:

- for federal government statistics, S&T and its two components, R&D and RSA;
- for industry statistics, R&D only;
- for education statistics, R&D only.

1. OECD, The Measurement of Scientific and Technical Activities (The Frascati Manual), (Paris: 1981), p. 25.

The RSA component of Statistics Canada data includes data collection (which for the mineral sector includes geological surveying and mineral exploration) and information services (again for minerals, this includes maps, core libraries, mineral inventories and other data bases, and reports and publications. In other words, geoscience data collection and mineral exploration are not considered R&D.

In the case of industrial R&D statistics, Statistics Canada relies on industry responses to a survey. Industry, however, tends to follow the Revenue Canada definition of R&D, reporting only those R&D expenditures that are eligible for special treatment under the Income Tax Act. As a consequence, some expenditures that might be considered routine upgrading of operations may be reported by industry as R&D, and some R&D expenditures may go unreported because they do not qualify for special tax treatment. On balance, it is difficult to determine whether industrial R&D expenditures in the mineral sector are under-reported or over-reported.

Two measures of **R&D intensity** are shown in this study: R&D as a percent of value added or of GDP value, and R&D as a percent of value of production or sales revenue. The former measure is preferable, since it relates R&D effort more closely to each sector's real economic contribution. However, in many instances, the second measure of value is the only one possible, given the available R&D data and economic data by industrial category.

Gross expenditure on research and development (GERD) is an aggregate of government (federal and provincial), industry, and other R&D expenditures. Because each of these categories is surveyed differently, there are no disaggregations available for GERD by industry sector; nor is it possible to construct such totals, since only the industry data are broken down by type of industry. GERD therefore can be used for international comparisons of overall R&D expenditures, and for an overview of trends in overall R&D intensity over time, when presented as a percent of gross domestic or national product, but not for economic sector comparisons.

Business enterprise R&D expenditures (BERD) are expenditures by industry. OECD and Statistics Canada present intramural expenditures only, in their BERD series, by type of industry. They also identify sectoral sources of industrial R&D funding (ie. government, industry, other).

A country is described as **export dependent** for a certain commodity or sector if domestic production of the commodity or in the sector exceeds domestic requirements, and therefore current production levels depend on export markets for sales. The commodity or sector may also play a

significant role in the trade balance, depending on the proportion of total exports it represents.

Import dependence refers to a situation where domestic production of a commodity or sector does not meet domestic requirements, whether for consumption or for processing and re-export.

The time-period covered in this study is generally 1980 to the most recent data available; some earlier data are provided, where available and relevant. This time period is very short for observing and analyzing economic trends, particularly for a sector such as mining where lead times are so long. It is also not a typical period for the mineral sector, with a strong beginning followed by deterioration of demand and prices for most commodities. However, it has been dictated by the availability of the data, particularly for R&D expenditures.

DATA SOURCES AND TREATMENT

The principal Canadian data sources are published data series and reports prepared by Statistics Canada, by Energy, Mines and Resources Canada, and by the OECD. In some cases, special tabulations of unpublished material have been received from these organizations as well. These sources are by far the most detailed and reliable of any available. The major drawbacks to their use are the time lags in some of the data series, lack or inconsistency of disaggregation, and the confidentiality requirements which prevent detailed breakdowns of some types of information.

A wide variety of additional published sources have been used for both qualitative and quantitative information, including government reports and publications, earth sciences journals and bulletins, and university and company reports.

Beyond these readily available published sources, CRS has sought additional Canadian data in 4 major areas: provincial government expenditures on mineral R&D activities; university activities related to mining & metallurgy; NSERC support for mineral-related R&D; and R&D activities of mineral industry firms and organizations. While the detail and timeliness of this additional data make it attractive, the lack of uniformity and unevenness of coverage are negative factors.

Conversions to constant 1981 dollars have been made using Statistics Canada's implicit GDP price index on a 1981 = 100 base, which is shown in appendix A.2. Over a long time period, such as 1970-88, deflation gives a distorted look to the more distant numbers compared to their current dollar values. However, the advantage of constant dollars is that they eliminate inflation effects, and can be used to measure real changes. The GDP price index was selected in preference to a mineral or R&D price index because of its applicability across the whole range of economic factors considered in this study.

ORGANIZATION

Chapter 2 looks at measures of the economic importance of the mineral industry in Canada. A set of general economic indicators is presented to provide an overview of the scope and relative importance of the mineral sector: value of production; value of mineral sector GDP, exports, and total employment in the industry.

Chapter 3 looks at federal support for mineral R&D activities, both in-house in CANMET, and externally, through mechanisms such as the Mineral Development Agreements (MDAs) with provincial governments, and research grants to universities through bodies such as NSERC.

Chapter 4 looks at the provincial role in mineral-related R&D.

Chapter 5 examines the role of industry in mineral R&D in Canada.

Chapter 6 looks at trends in education in mining and metallurgy in Canada, and some general trends in education in other scientific disciplines.

Chapters 7 and 8 compare the R&D funding levels among natural science and engineering disciplines including mining and metallurgy, and in the resource sectors, including the mineral industry.

Appendix A contains background statistical information. Appendix B contains the detailed results of a CRS survey of R&D funding in mining and metallurgy departments in Canadian universities.

2. ECONOMIC MEASURES OF THE CONTRIBUTION OF THE MINERAL SECTOR IN CANADA

INTRODUCTION

In order to place the mineral sector in the context of overall Canadian economic activity, the following are examined for Canada and the provinces:

- the value of crude mineral production;
- mineral industry GDP;
- mineral industry exports;
- employment in the mineral industry.

VALUE OF CRUDE MINERAL PRODUCTION

As an initial indicator of the mineral sector's economic activity, statistics on total value of crude minerals produced in Canada from 1980 to 1986 are presented in table 2.1 in 1981 dollars.

In this study, the mineral industry includes basic metals as well as the output of the mining industry. However, value of production figures for basic metals are not available as readily as they are for crude minerals. The closest proxy published in aggregate form by Statistics Canada for metals is sales of ferrous and nonferrous basic metal firms.

The decline in value in metallic minerals (ores and concentrates) is principally a reflection of falling mineral commodity prices, rather than cuts in volume of production, while the increase in coal reflects an increase of almost 60 percent in the volume of production over the period. Metallic ores and concentrates are by far the most important in terms of overall value of production, although they dropped in real value by 21 percent, while coal climbed by 30 percent over the period 1980-87. For a longer-term view of mineral production values, see appendix table A.1.

By province, EMR value of production figures are shown in table 2.2, and table 2.3 shows the contribution of each province to overall mineral production in Canada. Over the period 1980-87, Ontario mines have contributed an average value (1981 $) of $3.8 billion in non-oil and gas minerals, representing about 29 percent of all Canadian mine production, a share that has remained fairly constant over the period. British Columbia is second in terms of importance, with an average of $2.1 billion over the period, or about 16 percent of Canadian production. Quebec ranks third

Table 2.1 Value of Crude Mineral Production, Canada, 1980-87 (1981 $ billion)

	1980	1981	1982	1983	1984	1985	1986	1987	% Change 1980-87
Metallic	10.7	8.7	6.3	6.5	7.3	7.1	7.0	8.5	-20.6
Nonmetallic	2.8	2.7	1.8	1.7	2.0	2.2	2.0	1.9	-32.1
Structural materials	1.8	1.8	1.6	1.6	1.6	1.7	1.9	2.0	11.1
Coal	1.0	1.1	1.2	1.1	1.5	1.5	1.4	1.3	30.0
Total	16.3	14.3	10.9	10.9	12.4	12.5	12.3	13.7	-16.0

Source: Canadian Mining Journal, February issue, various years.

with an average of 15 percent of Canadian production. Alberta, Saskatchewan, and Newfoundland rank fourth, fifth, and sixth in importance.

GDP MEASURES

As a complement to the real value of primary mineral production, mineral sector gross domestic production (GDP) figures are recorded in table 2.4. These figures represent a close approximation of the actual value added to the Canadian economy by the industry. They are derived (by Statistics Canada) by subtracting the cost of inputs of goods and services from the total sales value of the specific industrial class or sector being described. The sum of all categories of GDP is equal to the total GDP for all Canada. The sum of production values, on the other hand, would far exceed total production values or GDP for all Canada, because it would incorporate multiple counting of goods from one category that are inputs in other categories.

These GDP statistics incorporate all activities associated with the mining, primary metal and fabricated metal industries in Canada. (see table 8.1 for SIC codes associated with these classifications). Total real GDP for the mining sector ranged from $7.0 billion to $9.7 billion over the 1980-87 period. Metals, with an average annual GDP value of $4.6 billion over the eight-year period, represent an average of 54 percent of mining industry GDP. In order to highlight the relative importance of the mineral sector in the overall economy, mineral industry GDP is compared to total Canadian GDP and the results are presented in table 2.5.

The contribution of primary mineral production to the GDP of each province and of Canada in 1984 is shown in table 2.6. While tables 2.3 and 2.4 show the relative importance of each province in mining production, table 2.6 shows both the relative GDP contribution by province and the relative importance of mining in the economy of each province.

Table 2.2 Value of Mine Production by Province, 1980-86
(1981 $ billion)

	1980	1981	1982	1983	1984	1985	1986	1987p
Newfoundland	1.15	1.03	0.60	0.71	0.83	0.71	0.65	0.59
Prince Edward Island	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nova Scotia	0.27	0.27	0.26	0.23	0.26	0.27	0.29	0.30
New Brunswick	0.41	0.53	0.46	0.44	0.52	0.42	0.40	0.54
Quebec	2.73	2.42	1.90	1.78	1.83	1.83	1.74	1.96
Ontario	5.10	4.11	2.84	3.17	3.76	3.71	3.77	4.32
Manitoba	0.83	0.58	0.40	0.51	0.54	0.56	0.53	0.70
Saskatchewan	1.57	1.44	1.00	0.86	1.23	1.05	0.96	1.13
Alberta	1.03	1.20	1.20	1.04	1.12	1.45	1.24	1.04
British Columbia	2.52	2.15	1.87	1.82	2.05	2.06	2.00	2.15
Yukon	0.40	0.24	0.15	0.06	0.06	0.05	0.14	0.35
Northwest Territories	0.41	0.40	0.43	0.49	0.62	0.52	0.53	0.63
Canada	16.42	14.37	11.10	11.10	12.82	12.63	12.25	13.71

Source: Derived from Canadian Mining Journal, February, various years. Totals may not match table 2.1 due to rounding.
Note: includes coal, excludes oil and gas.

Table 2.3 Provincial Contribution to Total Value of Canadian Mine Production, 1980-87
(percent)

	1980	1981	1982	1983	1984	1985	1986	1987p
Newfoundland	7.0	7.2	5.3	6.4	6.4	5.6	5.3	4.3
Prince Edward Island	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nova Scotia	1.7	1.9	2.3	2.1	2.0	2.1	2.4	2.2
New Brunswick	2.5	3.7	4.1	4.0	4.0	3.3	3.3	3.9
Quebec	16.6	16.8	17.1	16.0	14.3	14.5	14.2	14.3
Ontario	31.0	28.6	25.6	28.6	29.3	29.4	30.8	31.5
Manitoba	5.0	4.0	3.6	4.6	4.2	4.4	4.3	5.1
Saskatchewan	9.6	10.0	9.0	7.7	9.6	8.3	7.8	8.2
Alberta	6.3	8.3	10.8	9.4	8.8	11.5	10.1	7.6
British Columbia	15.3	15.0	16.8	16.4	16.0	16.3	16.3	15.7
Yukon	2.4	1.6	1.4	0.5	0.5	0.4	1.1	2.6
Northwest Territories	2.5	2.8	3.9	4.4	4.9	4.2	4.3	4.6
Canada	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: table 2.2.

Table 2.4 Mineral Industry GDP, by Source at Factor Cost, 1980-1987
(1981 $ million)

	1980	1981	1982	1983	1984	1985	1986	1987
Total metals	4,566	3,822	3,611	3,697	4,972	5,016	5,508	6,041
Total nonmetals[a]	1,612	1,647	1,322	1,485	2,039	2,046	1,968	2,131
Quarries and sand pits	329	315	246	278	372	342	394	460
Services incidental to mining	1,978	1,883	1,771	1,716	1,980	2,290	1,595	1,038
Total mining	8,485	7,666	6,950	7,176	9,363	9,694	9,465	9,670
Primary metal industry	4,710	5,101	3,832	4,325	5,541	5,577	5,537	5,996
Total	13,195	12,768	10,782	11,502	14,914	15,271	15,002	15,666
Fabricated metal industry	5,145	5,052	4,296	4,052	4,418	4,785	4,882	5,315
Total Canada	307,389	319,538	307,864	317,859	337,081	353,292	364,522	379,023

Source: Statistics Canada, 15-001 and 15-511.
[a] Includes coal.

Table 2.5 Mineral Industry GDP, by Source at Factor Cost, As a Percent of Total Canadian GDP, 1980-1987

	1980	1981	1982	1983	1984	1985	1986	1987
Total metals	1.49	1.20	1.17	1.16	1.48	1.42	1.51	1.59
Total nonmetals	0.52	0.52	0.43	0.47	0.60	0.58	0.54	0.56
Quarries and sand pits	0.11	0.10	0.08	0.09	0.11	0.10	0.11	0.12
Services incidental to mining	0.64	0.59	0.58	0.54	0.59	0.65	0.44	0.27
Total mining	2.76	2.40	2.26	2.26	2.78	2.74	2.60	2.55
Primary metal industry	1.53	1.60	1.24	1.36	1.64	1.58	1.52	1.58
Total	4.30	4.00	3.50	3.62	4.42	4.33	4.11	4.14
Fabricated metal industry	1.67	1.58	1.40	1.27	1.31	1.35	1.34	1.40

Source: table 2.4.

Table 2.6 Mining Industry[a] GDP by Province as Percent of Provincial GDP, 1984
(1981 $ million)

	Mining GDP	Provincial GDP	Mining GDP as % of Provincial GDP
Newfoundland	449.0	5,092.9	8.8
Prince Edward Island	0.1	1,096.3	0.0
Nova Scotia	253.0	9,042.2	2.8
New Brunswick	161.9	7,060.0	2.3
Quebec	658.5	85,272.0	0.8
Ontario	1,836.7	144,114.9	1.3
Manitoba	271.8	13,985.6	1.9
Saskatchewan	992.3	14,240.7	7.0
Alberta	1,368.6	50,261.0	2.7
British Columbia	925.6	43,069.3	2.1
Territories	477.2	1,577.7	30.2
Canada	7,394.9	374,812.5	2.0

Source: Statistics Canada, special compilation and 15-203.
[a] Excludes oil and gas.

Ontario, with the largest GDP value in 1984, has very small dependence on mining in its overall economy, while Newfoundland, which reached sixth in terms of contribution to total value of production in 1984, shows the second highest dependence on mining. Not surprisingly, the Territories are very dependent on the primary mineral industry, which provided 30 percent of their GDP in 1984.

EXPORTS

Table 2.7 presents the real value of Canadian exports of crude domestic minerals and primary metals over the eight-year period 1980-87. The annual average level of total mineral industry exports was about $13 billion over the eight years examined. In order to determine the relative importance of mineral industry exports, their values are shown as a percent of total Canadian exports in table 2.8.

Price effects are responsible for most of the decline in relative importance of mineral industry exports. The real value of exports fell 22 percent over the 1980-87 period, while their relative total importance declined by about 32 percent. Although the importance of mineral industry exports have declined, they still remain a significant part of Canada's total exports.

Table 2.7 Value of Canadian Domestic Primary Mineral and Metal Exports, 1980-86
(1981 $ billion)

	1980	1981	1982	1983	1984	1985	1986	1987
Metallic mineralsa	4.66	4.09	2.93	2.53	3.10	2.89	2.78	3.03
Nonmetallic mineralsb	1.48	1.58	1.18	1.07	1.34	1.65	1.49	1.25
Coalc	1.03	1.15	1.17	1.15	1.56	1.64	1.47	1.29
Total crude minerals	7.17	6.82	5.28	4.75	6.00	6.18	5.74	5.57
Primary metals	8.98	7.73	6.22	6.19	7.29	6.81	7.78	7.04
Total mineral industry	16.15	14.55	11.50	10.94	13.29	12.99	13.52	12.61
Total Canadian domestic exports	82.44	81.34	75.14	77.13	92.43	94.89	92.79	94.01

Source: Statistics Canada, 65-202.
a includes ores, concentrates and scraps.
b includes asbestos, sulphur and other crude nonmetallic minerals.
c includes coal plus other bituminous substances.

Table 2.8 Value of Crude Domestic Mineral Exports as Percent of Total Canadian Domestic Exports, 1980-86

	1980	1981	1982	1983	1984	1985	1986	1987
Metallic minerals	5.7	5.0	3.9	3.3	3.4	3.0	3.0	3.2
Nonmetallic minerals	1.8	1.9	1.6	1.4	1.5	1.7	1.6	1.3
Coal	1.2	1.4	1.6	1.5	1.7	1.7	1.6	1.4
Total crude minerals	8.7	8.4	7.0	6.2	6.5	6.5	6.2	5.9
Primary metals	10.9	9.5	8.3	8.0	7.9	7.2	8.4	7.5
Total mineral industry	19.6	17.9	15.3	14.2	14.4	13.7	14.6	13.4
Total Canadian exports	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: table 2.7.

EMPLOYMENT

As an additional indicator of the economic impact of the mineral sector in Canada, employment statistics are presented in tables 2.9, 2.10 and 2.11. Table 2.9 presents the total number of employees by subsectors, and table 2.10 shows the contribution of mineral production to employment in Canada.

Of the total number of employees in the mining industry, an average of 65 percent are recorded as working in metallic mineral production over the period examined, although the proportion is lower after 1983. Employment in metals has declined over the period, due both to improvements in labour productivity and to closures of some mines.

The relative importance of mineral industry employment is indicated in table 2.10. Less than one percent of the total labour force was allocated to crude mineral production as a whole over the eight-year period. However, this small proportion masks the heavy dependence of northern and remote regions on the mineral industry as the major economic activity and source of employment.

Provincial mining employment breakdowns are shown in table 2.11.

Table 2.9 Employment[a] in the Mining and Primary Metal Industries, 1980-1987
(thousands of employees)

	1980	1981	1982	1983	1984	1985	1986[p]	1987[p]
Metal mines	66	69	62	53	53	49	47	46
Nonmetal mines	17	16	14	13	14	13	12	12
Structural materials	4	4	3	3	4	4	5	6
Coal	11	11	13	12	12	12	11	12
Total mining	99	100	92	80	82	77	75	76
Smelters and refineries	36	35	30	30	29	29	26	26
Total Canadian employment	10,708	11,006	10,644	10,734	11,000	11,311	11,634	11,955

Source: EMR, from Annual Census of Mines, unpublished tabulation; and Statistics Canada 71-201.

[a] includes production and related workers, and administrative and office workers.

Table 2.10 Employment in the Mining and Metals Industries as a Percent of Total Employed Labour Force, 1980-1987

	1980	1981	1982	1983	1984	1985	1986p	1987f
Metal mines	0.62	0.63	0.58	0.49	0.48	0.43	0.40	0.38
Nonmetal mines	0.16	0.15	0.13	0.12	0.13	0.12	0.10	0.10
Structural materials	0.04	0.04	0.03	0.03	0.04	0.04	0.04	0.05
Coal	0.11	0.10	0.12	0.11	0.11	0.11	0.10	0.10
Total mining	0.92	0.91	0.86	0.75	0.74	0.68	0.64	0.63
Smelters and refineries	0.34	0.32	0.28	0.28	0.26	0.26	0.22	0.22

Source: table 2.9.

Table 2.11 Employment in Mining by Province, 1980-1986

	1980	1981	1982	1983	1984	1985	1986
Newfoundland	5,735	5,364	3,947	3,020	2,918	2,771	2,532
Prince Edward Island	0	0	0	0	0	0	0
Nova Scotia	5,093	4,909	5,447	4,992	3,810	3,739	3,965
New Brunswick	2,554	3,093	2,918	2,626	2,940	3,068	3,145
Quebec	23,431	22,201	18,671	16,387	16,428	15,366	14,303
Ontario	30,737	31,249	29,176	26,004	26,413	24,433	24,263
Manitoba	5,102	5,129	4,417	4,060	4,083	3,941	3,524
Saskatchewan	6,451	7,354	6,099	5,416	6,503	6,183	5,771
Alberta	341	3,289	3,268	3,265	3,036	3,074	2,873
British Columbia	13,027	14,594	14,747	12,212	12,879	12,385	11,558
Yukon and NWT	3,205	3,286	3,097	2,432	2,836	2,703	2,561
Total mining	98,974	100,468	91,787	80,413	81,846	77,663	74,495

Source: Statistics Canada 26-201 and 26-213.

EXPLORATION

Exploration is included here because it is an economic activity in its own right, an economic activity generated by expectations of potential revenues for the mineral industry. Although there is no "value of production" data series to attach to the exploration sector, the expenditures themselves provide employment, and result in purchases of materials, equipment, and services. The major determinants of the level of exploration expenditure in a particular jurisdiction are mineral prices, geological potential, the quality of available geoscience data, and government incentive programs.

Nonfuel mineral exploration expenditures by province are presented in constant dollars in table 2.12 and in percentage form in 2.13. On average, 29 percent of all Canadian expenditures occurred in Quebec in the nine year period 1980-88. The years 1986 to 1988 were exceptional in Quebec in terms of exploration activity, largely as a result of the Quebec government's incentive and assistance programs. Ontario and British Columbia rank second and third in terms of exploration expenditures over the 1980-88 period, with 20 and 19 percent of Canadian expenditures respectively.

Table 2.12 Mining Exploration Expenditures[a], by Province, 1980-1988
(1981 $ million)

	1980	1981	1982	1983	1984	1985	1986	1987[i]	1987[p]	1988[i]
Atlantic Provinces	45.4	50.6	21.4	18.1	21.4	23.0	32.8	22.1	24.4	32.7
Quebec	80.7	96.0	68.9	72.8	97.7	109.4	188.2	208.7	334.9	341.5
Ontario	80.8	101.8	82.2	81.4	99.3	75.5	101.0	115.0	132.7	140.8
Manitoba	25.0	23.8	13.9	11.0	15.7	28.5	17.4	11.5	13.4	13.6
Saskatchewan	73.4	52.1	47.4	24.3	27.3	25.2	25.9	11.4	28.4	33.3
Alberta	23.5	30.2	23.8	14.1	9.8	15.9	9.1	3.9	3.1	3.8
B.C.	123.6	139.9	71.3	79.3	94.8	75.9	59.5	54.5	81.5	98.9
Territories	84.9	90.9	78.0	27.0	40.1	45.9	34.3	24.2	39.2	24.7
Canada	537.4	585.3	406.9	328.0	406.2	399.3	468.4	451.4	657.6	688.8

Source: Statistics Canada, 61-216.
[a] Includes only general exploration in search of new orebodies. Includes costs of surveying, assessment, lease rentals, diamond drilling, geological, geophysical work and exploration shafts.
[i] Intentions.

Table 2.13 Mining Exploration Expenditures, by Province, 1980-1988
(Percent Contribution)

	1980	1981	1982	1983	1984	1985	1986	1987[i]	1987[p]	1988[i]
Atlantic Provinces	8.5	8.7	5.3	5.5	5.3	5.8	7.0	4.9	3.7	4.7
Quebec	15.0	16.4	16.9	22.2	24.1	27.4	40.2	46.2	50.9	49.6
Ontario	15.0	17.4	20.2	24.8	24.4	18.9	21.6	25.5	20.2	20.4
Manitoba	4.6	4.1	3.4	3.4	3.9	7.1	3.7	2.5	2.0	2.0
Saskatchewan	13.7	8.9	11.7	7.4	6.7	6.3	5.5	2.5	4.3	4.8
Alberta	4.4	5.2	5.9	4.3	2.4	4.0	1.9	0.9	0.5	0.6
B.C.	23.0	23.9	17.5	24.2	23.3	19.0	12.7	12.1	12.4	14.4
Territories	15.8	15.5	19.2	8.2	9.9	11.5	7.3	5.4	6.0	3.6
Canada	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: table 2.12.
[i] Intentions.

CONCLUSION

The mineral industry has represented an average of about 4.0 percent of total Canadian GDP over the 1980-87 period. However, during the 1980s the measure has declined in relative terms: in 1980 the sector represented $13 billion or 4.3 percent of GDP; by 1987 total mineral industry GDP had climbed to $16 billion but had fallen to 4.1 percent of total GDP. Weak prices for minerals relative to other goods are largely responsible for this divergence in trends (see appendix table A.3).

Other indicators of the economic importance of the sector have also shown a downward trend. The real value of exports for the total mineral industry declined from $16 billion in 1980 to $13 billion in 1987, a 22 percent drop over the eight years examined. The share of mineral industry exports in total Canadian exports declined from 20 to 13 percent, with the largest single decline occurring between 1981 and 1982. Nevertheless, mineral industry exports still represent an important component of total Canadian exports.

The mineral industry has less relevance for the overall economy in terms of employment than it does in terms of GDP and exports. The sector represented an average of only about one percent of the total employed labour force over the 1980-87 period. However, these aggregations mask very high levels of dependence on mineral industry employment in some regions.

Of these three areas - GDP, exports, and employment - the mineral sector plays the most important role in the area of Canadian exports. In each area, the mineral industry has declined in importance over the eight-year period examined. While the mineral sector is relatively less significant economically than in 1980, it retains an important role in the overall Canadian economy and particularly in some provinces. In remote regions, it is frequently the only viable economic activity for the generation of new wealth.

3. FEDERAL R&D SUPPORT FOR THE MINERAL SECTOR

INTRODUCTION

Federal R&D support for the mineral industry arises largely within the science and technology (S&T) expenditures of Energy, Mines and Resources Canada (EMR). Federal S&T activities include intramural undertakings, as well as the distribution of funds to provincial governments and to research workers in universities and industry. S&T support is subdivided into two components: research and development (R&D) and related scientific activities (RSA).

This chapter presents expenditure data in two major categories: first, federal government intramural expenditures on mineral-related R&D activities; and second, federal funding of extramural mineral-related R&D, mainly at universities. The chapter begins with an overview of total federal government S&T and R&D expenditures to set its mineral R&D activities into context.

OVERVIEW OF FEDERAL S&T AND R&D EXPENDITURES

Table 3.1 shows the distribution of S&T expenditures in all aspects of science and technology for the major federal departments. In real terms EMR's S&T funding increased from $215.1 million to $308.7 million from 1980/81 to 1987/88, representing an increase of 44 percent over the period. Seven other departments received funding increases of more than 40 percent over the period, including Transport Canada, Agriculture Canada, the Department of National Defence, IDRC, MRC, NSERC and DRIE. It is not clear to what extent these changes are the result of changes in definitions, data handling, or reporting methods, or represent real increases in S&T activities.

Federal support for S&T as a percent of official government expenditure by department is shown in table 3.2. Some of the agencies that are devoted exclusively to research show ratios of greater than 100 percent, indicating the use of non-budgetary funds, or research undertaken for other departments or sponsors.

R&D expenditures are presented in table 3.3 for a selected group of departments with resource-sector interests. These figures are compared to the total S&T statistics in order to indicate the percent of S&T that is defined as R&D in the federal data series. For the Department of Energy, Mines and Resources, R&D represents almost two thirds of S&T. The table

Table 3.1 Federal Expenditures on Science and Technology, by Department, 1980/81 and 1987/88

	1980/81			1987/88		
	S&T Expenditures (1981 $ million)	As % of Spending on S&T	As % of Government Spending	S&T Expenditures (1981 $ million)	As % of Spending on S&T	As % of Government Spending
Agriculture	203.5	8.1	20.8	302.4	9.4	22.4
AECL	111.7	4.5	12.0	109.8	3.4	83.9
CIDA	40.6	1.6	5.5	54.6	1.7	3.4
Communications	74.9	3.0	50.8	39.2	1.2	18.2
EMR	215.1	8.6	6.2	308.7	9.6	18.2
Environment	303.8	12.1	51.1	304.7	9.5	51.2
Fisheries & Oceans	158.8	6.3	39.0	159.0	5.0	37.2
IDRC	44.1	1.8	94.8	75.5	2.4	92.0
MRC	91.0	3.6	100.2	133.2	4.2	100.1
National Defence	114.6	4.6	2.0	190.9	6.0	2.4
National Health & Welfare	80.3	3.2	0.5	102.2	3.2	0.5
NRC	254.7	10.1	105.5	347.8	10.8	110.1
NSERC	180.7	7.2	100.7	256.7	8.0	100.2
DRIE	111.6	4.4	16.2	178.2	5.6	20.0
SSHRC	47.4	1.9	101.9	53.2	1.7	101.1
Statistics Canada	174.6	6.7	114.3	210.8	6.6	127.9
Transport Canada	19.3	0.8	0.8	29.9	0.9	1.7
Others	285.3	11.4	0.8	347.4	10.8	0.8
Total federal S&T expenditures	2,512.1	100.0	3.6	3,204.3	100.0	3.8
Total federal government expenditure	69,077.5	-	100.0	85,248.5	-	100.0

Source: Statistics Canada, Federal Scientific Activities 1987-88, 88-204 and appendix table A.4.

Table 3.2 Federal Support for Science and Technology as a Percentage of Total Government Spending by Department, 1980/81 - 1987/88[a]

	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87[p]	1987/88[p]
Agriculture	20.8	18.8	22.8	25.8	22.3	23.1	17.4	22.4
AECL	12.0	36.4	41.1	41.1	46.1	50.9	71.2	83.9
CIDA	5.5	5.2	5.2	4.4	3.7	4.1	2.9	3.4
Communications	50.8	51.4	20.7	35.9	33.2	29.6	24.4	18.2
EMR	6.2	21.5	20.7	35.9	33.2	29.6	24.4	18.2
Environment	51.1	45.6	42.3	41.4	45.3	49.6	50.6	51.2
Fisheries and Oceans	39.0	35.5	39.9	36.5	36.9	40.6	40.3	37.2
IDRC	94.8	97.7	90.8	95.1	93.5	95.1	91.4	92.0
MRC	100.2	100.4	100.4	100.5	100.0	100.4	100.2	100.1
National Defence	2.0	2.0	2.1	2.0	2.2	2.3	2.3	2.4
National Health and Welfare	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.5
NRC	105.5	105.0	104.6	103.9	103.5	101.7	112.5	110.1
NSERC	100.7	100.5	1200.1	100.4	100.2	100.4	100.2	100.2
DRIE	16.2	26.1	13.9	15.9	16.2	19.1	19.0	20.0
SSHRC	101.9	99.8	101.4	100.8	100.3	101.1	100.9	101.1
Statistics Canada	114.3	111.2	115.7	120.9	119.8	125.7	116.2	127.9
Transport Canada	0.8	1.3	1.2	1.4	1.5	1.4	1.6	1.7
Others	0.8	0.9	0.8	0.8	0.7	0.7	0.8	0.8
Total spending	3.6	4.1	3.9	3.9	3.9	3.8	3.9	3.8

Source: Appendix tables A.4 and A.5.
[a] For 1987/88 budgeted expenditure rather than actual expenditure is used.

Table 3.3 Distribution of S&T and R&D Expenditures, by Selected Federal Departments, 1980/81 and 1987/88 (1981 $ million)

	1980/81			1987/88P			% Change 1980/81-1987/88	
	S&T	R&D	R&D as % of S&T	S&T	R&D	R&D as % of S&T	S&T	R&D
Agriculture	203.5	179.5	88.2	302.4	273.3	90.4	48.6	52.3
EMR[a]	215.1	138.1	64.2	308.7	189.9	61.5	43.5	37.5
F&O	158.8	90.3	56.8	159.0	86.3	54.3	0.1	-4.4
IDRC	44.1	36.1	81.8	75.5	59.8	79.2	71.2	65.6
NRC	254.7	214.0	84.0	347.8	305.3	87.8	36.6	42.7
NSERC	180.7	162.7	90.0	256.7	222.1	86.5	42.1	36.5

Source: Statistics Canada, 88-204.

[a] R&D funding in the natural sciences and engineering only; does not include social sciences and humanities R&D.

also indicates that EMR's real expenditures on research and development have increased by 38 percent over the 7-year period shown, somewhat less than S&T at 44 percent.

MINERAL JURISDICTION AND POLICIES

Canada has a federal system of government, with 10 provinces and two territories, each with its own government and fields of jurisdiction, and the national or federal government based in Ottawa. Although the responsibilities of each jurisdiction are defined by the Constitution Act and other documents and conventions, there are many overlapping areas that have evolved by agreement, or in some cases by lack of agreement, over the years. This is true in the case of jurisdiction over the mineral industry, which would seem in constitutional terms to be exclusively a provincial concern. For example, the provincial governments have ownership of and regulatory power over mineral resources within their borders; they have jurisdiction over regulation of exploration, mining, and primary production, as well as over environmental, health and safety concerns and they levy income taxes, mining taxes and royalties; they also share, with the Geological Survey of Canada, responsibility for the provision of the geoscience data base within their borders.

Nevertheless, the federal government is also very active with respect to minerals, including mineral-related research and development. The federal government exercises similar (i.e. provincial type) control over minerals in the two territories including the Arctic Islands, and the seabed of the continental shelf. In addition, the federal government has been involved in many aspects of the mineral industry and earth sciences in all of Canada through its Geological Survey responsibilities as noted above, and its national and international scientific activities, as well as through its jurisdiction over interprovincial and international trade and commerce, fiscal and monetary powers, statistical data collection, navigation, shipping, fisheries, and overall undertakings involving more than one province. It also levies personal and corporate income taxes, manufacturers' sales tax, excise taxes, and import tariffs on businesses in Canada, including the mineral sector.

Figure 3.1 lists some of the federal departments and agencies that have mineral related interests, as regulators, performers of in-house R&D, or as sources of funding for external R&D activities. Only EMR has minerals as the principal focus of its activities. The major sources of federal government funding for extramural mineral-related R&D are EMR and the National Science and Engineering Research Council (NSERC), which funds

most university research and some industry research in Canada, although mineral (mining and metallurgy) grants represent only a small proportion of NSERC's overall R&D funding activities.

Federal government activities, particularly in geoscience research and data collection, have played an important role in the development of the Canadian mineral industry from its earliest days. Frequently, this involvement has developed in an ad hoc manner, often in response to pressures unrelated to minerals. Early surveying activities, for example, were designed more for railroad planning and for the realization of aspirations of nationhood than for mineral development, although the mineral industry spin-off benefits were considerable. Subsequent development of the Geological Survey of Canada (GSC) into a first-rank geoscience organization has been a continuing source of strength for earth sciences and mineral exploration activities in Canada.

Federal government interest in mining and mineral processing began with the establishment of the Mines Branch in 1907, and has continued with the evolution of that branch into the Canada Centre for Mineral and Energy Technology (CANMET). Early justification for federal involvement in this area of R&D rose out of defence needs in World Wars I and II.

Until the 1970s, federal policies generally encouraged growth in the mineral industry through a wide range of programs including geoscience data collection and mineral-related R&D, exploration and development incentives, fiscal incentives, and provision of infrastructure for new mineral developments and transportation of mineral products. The 1970s saw a policy shift towards redistribution of resource-industry revenues, inspired by short-lived but spectacular price rises for oil and gas and some minerals, and by fears (also short-lived) of resource depletion. The redistribution phase concentrated on tax changes, with both federal and provincial governments seeking to increase their share of both profit-based and nonprofit taxes.

In the present period, the federal government has been described as moving towards "maturity management" for the mineral sector[1]. There are pressures, both political and economic, for backing away from special incentives and from across-the-board subsidization for any economic sector. This does not preclude R&D assistance for adapting to technological change or other short-term adjustment programs, but it may constrain long-term support programs.

1. D. Yudelman, Canadian Mineral Policy, Past and Present: The Ambigious Legacy, (Kingston: Centre for Resource Studies, 1985).

Department or Agency	Principal Mineral-Related Activities
Energy, Mines and Resources	- intramural R&D in earth sciences, minerals and energy - geoscience data collection - all Canada - some funding support for extramural R&D (provinces, industry, universities)
Indian Affairs and Northern Development	- provincial-type mineral responsibilities in the Yukon and Northwest Territories
Environment	- mine tailings and smelter emission control standards
Transport Canada	- provision and operation of transportation infrastructure, some of which is largely dedicated to mineral transportation
National Science and Engineering Research Council	- funding of all fields of science and engineering, mainly in universities
National Research Council	- in-house R&D in many fields of science and engineering - some external R&D funding
Canadian International Development Agency	- support for external aid projects including mineral-related projects, chiefly to Canadian universities and firms
International Development Research Corporation	- support for external aid projects including mineral-related projects, chiefly to Canadian universities and firms

Figure 3.1 Federal Department Activities and/or R&D Support in Mineral Industry

ENERGY, MINES AND RESOURCES ACTIVITIES

The mandate of the federal department of Energy, Mines and Resources covers the mining, metallurgy, and energy sectors, as well as earth sciences interests. The department is responsible for the development and implementation of energy and mineral policies and programs within its sphere of jurisdiction, based on research, data collection and analysis in the various mineral-related sectors. Its activities are divided into two major components: the Energy Program, and the Minerals and Earth Sciences Program. The Energy Program includes responsibility for ensuring that energy research capabilities are adequate to support Canada's energy objectives. The Minerals and Earth Sciences Program includes responsibilities for establishing policies and strategies to ensure that the minerals and metals sector contributes with maximum effectiveness to the economy of Canada, and for ensuring that adequate technology is available for this purpose. CANMET and the GSC are funded within this program.

In order to set the mineral R&D program into context, table 3.4 sets out the major expenditure categories for these two programs. Annual expenditures on S&T are shown in table 3.5. Comparing the two tables, it appears that in 1984/85, for example, S&T expenditures represented about 8.2 percent of the department's budget, and R&D about 5.4 percent. The proportion is much different, however, within the Mineral and Earth Sciences Program, where R&D (taken as $189.9 million in table 3.5 minus the $1.8 million shown as energy R&D in table 3.4) represents over 75 percent of the budget, and S&T therefore is probably over 80 percent. Real expenditures in S&T increased by 44 percent over the period, although there was a slight drop in the last two years shown. R&D expenditures increased 38 percent, with a sharp drop in 1986/87 and a small drop in 1987/88.

An average of 73 percent of the S&T funds was spent intramurally, and about 15 percent was distributed to industry in the form of contracts and grants. In 1982/83 the proportion going to the provinces fell sharply, largely due to the winding down of the $90 million Alberta Energy Resource Research Fund.

Table 3.4 EMR Expenditures by Program and Activity, Selected Years
(1981 $ thousand)

	1982/83				1984/85			
	Operating	Capital	Grants, Contributions & Transfer Payments	Total	Operating & Capital	Capital	Grants, Contributions & Transfer Payments	Total
Administration total	16,899	314	66	17,279	20,840	1,941	0	22,780
ENERGY PROGRAM								
Energy policy analysis sector[a]	20,826	236	163	21,225	9,800	255	2,124	12,179
Petroleum sector[b]	13,740	197	4,084,567	4,098,504	7,166	111	3,129,443	3,136,720
Conservation and non-petroleum energy sources	48,023	458	408,480	456,961	55,671	524	358,505	414,699
Energy research and development	2,377	15	0	2,392	1,600	11	148	1,758
Petroleum incentives admin.	0		0	0	14,613	138	1,465,650	1,480,401
Canada oil and gas lands admin.	2,989	111	0	3,100	5,681	112	17,753	23,546
Program management & support[c]	14,564	19	0	14,583	15,399	286	0	15,685
Other[d]	0	0	-2,433,978	-2,433,978	167	0	-1,866,345	-1,866,178
Total Energy Program	102,520	1,037	2,059,232	2,162,790	110,095	1,437	3,107,278	3,218,810
MINERALS AND EARTH SCIENCE PROGRAM								
Mineral development	7,391	6	257	7,655	6,381	64	1,588	8,033
Canada Explosives Act	1,325	56	0	1,381	1,456	77	0	1,533
Minerals technology	14,162	1,401	42	15,606	19,139	4,254	16	23,410
Energy technology	25,722	6,767	413	32,902	30,391	6,419	269	37,079
Geological surveys	40,489	2,221	39	42,750	51,687	5,764	52	57,503
Earth physics	10,790	681	25	11,496	12,552	2,305	0	14,856
Polar Continental Shelf Project	5,150	28	0	5,177	5,552	38	0	5,590
Remote sensing	14,250	12,284	2,112	28,646	14,808	9,709	3,463	27,981
Surveys and mapping	39,135	1,690	62	40,886	40,073	5,310	64	45,447
Other	18,340	230	1,284	19,854	21,451	374	1,485	23,310
Total minerals and earth science program	176,754	25,365	4,234	206,353	203,489	34,314	6,937	244,740
Total EMR	296,173	26,715	2,063,534	2,386,421	334,424	37,692	3,114,214	3,486,330

Table 3.4 EMR Expenditures by Program and Activity (continued)
(1981 $ thousand)

	1985/86				1986/87			
	Operating	Capital	Grants, Contributions & Transfer Payments	Total	Operating	Capital	Grants, Contributions & Transfer Payments	Total
Administration total	32,403	1,059	0	33,462	32,610	1,681	0	34,291
ENERGY PROGRAM								
Energy policy analysis sector[a]	7,411	153	251	7,815	7,397	157	332	7,886
Petroleum sector[b]	7,070	110	929,077	936,257	6,401	136	79,350	85,886
Conservation and Non-Petroleum energy sources	57,988	767	197,228	255,983	52,269	529	48,866	101,664
Energy research and development	1,494	15	291	1,801	797	6	799	1,602
Petroleum incentives admin.	15,436	40	1,225,293	1,240,769	14,393	107	753,898	768,398
Canada oil and gas lands admin.	5,392	25	70,363	75,780	4,998	216	16,547	21,760
Program management & support[c]	1,322	0	316	1,638	1,192	13	378	1,583
Other[d]	-1,662	0	- -992,072	- -993,734	-443	0	-68,689	-69,132
Total Energy Program	94,452	1,111	1,430,746	1,526,306	87,004	1,164	831,482	919,650
MINERALS AND EARTH SCIENCE PROGRAM								
Mineral development	7,692	40	7,134	14,865	8,421	152	12,672	21,245
Canada Explosives Act	1,759	66	0	1,825	1,660	48	0	1,708
Minerals technology[e]	53,401	7,819	375	61,596	53,170	5,194	300	58,664
Energy technology[e]	na	na	na	na	na	na	na	na
Geological surveys	63,196	3,928	0	67,124	65,797	3,980	0	69,777
Earth physics	12,598	2,379	0	15,337	11,505	2,253	0	13,578
Polar Continental Shelf Project	5,830	41	0	5,871	5,142	571	0	5,713
Remote sensing	20,154	10,845	6,291	37,290	19,929	5,601	7,598	33,218
Surveys and mapping	45,404	3,477	62	48,943	44,274	4,264	60	48,598
Other	4,406	236	3,571	8,214	6,825	259	3,655	10,739
Total minerals and earth science program	214,801	28,830	17,433	261,064	216,723	22,322	24,286	263,330
Total EMR	341,656	31,000	1,448,179	1,820,832	336,337	25,167	855,768	1,217,271

Source: Government of Canada, Public Accounts of Canada 1985/86 and 1986/87, and EMR, Annual Report 1982/83 and 1984/85.

[a] Includes the Petroleum Monitory Agency.

[b] Includes Oil Pricing and Compensation Programs, Emergency Planning and the Energy Surplus Allocation Board.

[c] Includes Energy Public Information and Employee Benefit Plans.

[d] Includes Petroleum Compensation Revolving Fund, Environmental Studies Revolving Fund and funds available from the Province of Alberta for market development.

[e] Mineral and energy technology data combined for 1985/86 and 1986/87.

Table 3.5 EMR Funding of S&T and R&D, 1980/81 - 1987/88

	80/81	81/82	82/83	83/84	84/85	85/86	86/87	87/88[p]
R&D Funding[a] (1981 $ million)	138.1	153.5	156.5	169.0	189.9	213.8	192.4	189.9
S&T Funding (1981 $ million)	215.1	232.2	235.6	252.6	285.4	316.9	311.4	308.7
Distribution of S&T Funds (percent)								
EMR intramural	67	70	78	73	74	74	74	73
Industry	14	13	13	16	16	17	14	14
University	2	1	2	2	2	2	2	1
Prov. govt	15	14	3	6	4	na	na	na
Other	2	2	4	3	4	na	na	na

Source: Statistics Canada, Cat 88-204.
[a] R&D funding in the natural sciences and engineering only: does not include the social sciences and humanities.

The remainder of this chapter focuses on EMR's mining and metallurgy R&D activities and support, both in-house and extramural, plus other federal initiatives in this area. Chapter 8 includes a brief discussion of federal earth-science-related activities, which help provide the geoscience data base and theoretical understanding necessary for locating mineral deposits.

The Canada Centre for Mineral and Energy Technology (CANMET)

Introduction

CANMET is the mineral and energy technology branch of EMR. Most of the budget (about 86 percent in the current fiscal year 1988/89) is classified as S&T, and R&D accounts for 79 percent of S&T, or 68 percent of the total budget. CANMET's goals are:

- to ensure that advanced technology is available for Canadian industry to meet the national requirements for extraction, processing and utilization of mineral resources;
- to provide the technical knowledge necessary to formulate mineral and energy policy;
- to facilitate the efficient exploitation of Canada's mineral and energy resources, taking into account health, safety and

environmental concerns.3

Work is conducted in laboratories in Ottawa, Devon Alberta, Sydney Nova Scotia, and Elliot Lake Ontario. In terms of R&D objectives, the principal focus is currently in three areas (with approximate allocation of resources shown in brackets):

- productivity R&D to promote maximum efficiency and competitiveness in all facets of the mining, materials, metals, and fossil fuels industries (60 percent);
- policy R&D in support of development and implementation of departmental and general government policies (10 percent);
- protection R&D supporting health and safety in the workplace, environmental control in industrial processes, quality and performance of industrial products and national and international standards (30 percent).[4]

CANMET's research results are communicated to its clients in industry, universities and provincial governments and other federal agencies through publications and data bases, joint ventures, contracts, and technology transfer activities. Its research direction and activities are influenced by an advisory committee and set of subcommittees made up of representatives from industry, universities, and provincial and other research organizations.

The allocation of CANMET's resources saw a major shift to energy R&D in the mid-1970s, following the oil price increases of 1973. This trend reversed in the mid-1980s, as economic and political pressures led to cutbacks in energy activities and a renewed emphasis on mineral technology and productivity. This study will focus on the mining and metallurgy aspects of CANMET's R&D, rather than the energy aspects. For example, coal mining is included, but coal utilization is not.

It should be noted that A-base funding is an important indicator of trends in S&T funding, as the A-base is the basic budgetary funding voted annually to maintain the continuing operations which fulfill the agency's mandate. A-base funding is traditionally expected to be fairly stable in the short run, and it covers programs expected to continue for the long run. "Add-on" or "sunset" funding, on the other hand, is allocated for specific purposes and for specific lengths of time. The Federal/Provincial Mineral Development Agreements discussed below are an example of add-on funding. Add-on funding is much more volatile than the A-base, as it depends on the quality and political attractiveness of program proposals, as well as on the Government's fiscal position.

3. Government of Canada, Budget Estimates, Part III, Energy Mines and Resources Canada, 1988/89, p. 4.42
4. CANMET Business Plan 1988-91, (1987), pp. 9-10

CANMET Funding Trends

CANMET's Mineral Technology activities are divided into four major subactivities:

- mining, excluding coal;
- coal mining and preparation, including oil sands;
- mineral processing;
- metals and materials.

Table 3.6 shows that the funding for these 4 sub-activities has declined substantially even in the current dollar terms used here, over the period 1985/86 to 1988/89; mining by 23 percent and mineral processing by 21 percent (see table 3.10 for the real change in 1981 dollars). Table 3.7 shows the person/year allocations, which declined very slightly.

There is some cost recovery within the research programs, through contracts and joint ventures with industry and with provincial governments. Table 3.8 shows actual cost recoveries for 1985/86 and 1986/87, estimates for 1987/88, and targets to 1990/91.

While the targets anticipate a growth in cost recovery, they do not anticipate an increase in government funding to 1990/91. The A-base total, for example, actually fell by about 8 percent between 1985/86 and 1986/87, and is targeted to remain at about the same level until 1990/91 (see table 3.9), which translates into a real decline of 21.5 percent. The Mineral Development Agreement (MDA) funding picked up some of the slack in 1986/87, but will drop until 1990/91, leaving CANMET's overall budget down by about 19 percent in real terms from 1985/86 unless new programs are initiated.

Table 3.6 CANMET Mineral and Energy Technology Resource Allocations by Sub-Activity, 1985/86 - 1988/89
(current $ thousand)

	1985/86	1986/87	1987/88[e]	1988/89[f]
Mining	7,729	6,691	6,334	5,982
Coal mining and preparation	6,023	6,437	6,179	6,990
Mineral processing	17,589	16,466	14,741	13,890
Metals and materials	10,279	10,539	10,546	10,227
Fuels technology	26,180	25,474	23,370	25,937
Technology information	2,495	2,672	2,812	2,110
Technical services	3,092	3,157	2,631	2,232
Management & support	4,906	4,318	5,423	3,715
Canada Explosives Research Lab	684	704	891	839
Contributions	19	369	980	na
Total	78,996	76,827	73,907	71,922

Source: CANMET Research Program Office. for 1985/86 and 1986/87;
CANMET Business Plan 1988-91, for 1987/88 and 1988/89.

Table 3.7 CANMET Person-Year Allocations for Mineral and Energy Technology, 1985/86 - 1988/89

	1985/86	1986/87	1987/88e	1988/89f
Mining	71	71	68	68
Coal mining & preparation	59	59	56	55
Mineral processing	188	184	181	182
Metals and materials	141	140	137	137
Fuels technology	178	179	178	178
Technology information	36	36	35	35
Technical services	60	59	56	56
Management & support	56	59	58	58
Canada Explosives Research Lab	14	14	14	14
Total	803	801	783	783

Source: CANMET Research Program Office, 1985/86 and 1986/87; CANMET Business Plan 1988-1991, 1987/88 and 1988/89.

Table 3.8 CANMET Research Program Cost Recovery, 1985/86 - 1990/91 (current $ thousand)

	1985/86	1986/87	1987/88e	1988/89a	1989/90a	1990/91a
Coal Research Lab	62	268	300	350	400	400
Energy Research Lab	265	235	235	400	500	600
Mining Research Lab	87	74	145	195	225	250
Mineral Science Lab	176	296	296	400	500	600
Phys. Metallurgy Lab	223	482	250	280	570	500
Technology Info.	31	35	35	50	65	70
Other	9	1	-	-	-	-
Total	853	1,390	1,261	1,675	2,260	2,420

Source: CANMET Business Plan 1988-1991.
[a] figures for 1988/89 and thereafter are targets.

Table 3.9 CANMET Funding by Type of Funds, 1985/86 - 1990/91
(current $ million)

	1985/86	86/87	87/88e	88/89f	89/90f	90/91f
A-Base	43.8	40.3	40.5	40.2	40.2	40.2
Reconfirmation: Energy R&Da	31.8	30.7	29.7	29.3	28.9	28.9
Sunset: MDAs	3.4	5.5	3.2	2.4	1.2	0.0
Other	0.0	0.3	0.5	0.0	0.0	0.0
Total	79.0	76.8	73.9	71.9	70.3	69.1

Source: CANMET Research Program Office and Business Plan 1988-1991.
a Subject to reconfirmation; controlled by the Interdepartmental Panel on Energy R&D (IPERD)

Table 3.10 Allocation of CANMET Funding, 1985/86 and 1987/88
($ thousand)

	1985/86		1987/88	
	$ current	$ 1981	$ current	$ 1981
Mining				
salary	3,024	2,471	3,509	2,716
operating	600	490	877	679
capital	3,059	2,499	361	279
contracts	1,046	855	1,587	1,228
total	7,729	6,315	6,334	4,902
Coal mining & preparation				
salary	2,555	2,087	2,925	2,264
operating	856	699	1,180	913
capital	1,047	855	957	741
contracts	1,565	1,279	1,117	865
total	6,023	4,921	6,179	4,783
Mineral processing				
salary	8,023	6,555	8,946	6,924
operating	3,687	3,012	1,666	1,289
capital	946	773	651	504
contracts	4,933	4,079	3,478	2,692
total	17,589	14,370	14,741	11,409
Metals and minerals				
salary	6,060	4,951	6,610	5,116
operating	1,290	1,054	1,436	1,111
capital	757	618	949	734
contracts	2,172	1,775	1,551	1,200
total	10,279	8,398	10,546	8,163

Source: CANMET Research Program Office.

At present, the decline in the A-base affects the nonfuel sector most, since it derives very little of its funding from the energy R&D funds. Energy funds, on the other hand, are subject to reconfirmation and therefore are unpredictable over the long term. Since these short-term funds account for about 78 percent of fuels technology funding, this activity is particularly vulnerable to changing priorities.

So far, the cuts have primarily affected the funding for operating and capital costs in the case of mining and mineral processing, and external contracts in the case of coal mining and metals and materials, as shown in table 3.10. The projections of person-year allocations shown in table 3.7 suggest that salaries will continue to climb, at the expense of the other categories, unless person-years, capital and/or contracts are traded for operating dollars.

CANMET Mineral R&D Activities

Since this study's main interest is R&D funding trends, the description of CANMET's mineral R&D activities will consist mainly of tables of expenditures by sub-sub-activity taken from CANMET Resource Allocation sources. There will be no qualitative descriptions or evaluation of research areas or projects. This data series is available only from 1985/86.

Table 3.11 shows total funding (A-base and add-ons) within the mining, coal, processing, and metals and materials activities. The major decrease in both mining and mineral processing R&D is in environmental-related activities. The decrease in mining is deceptive, and results from the completion of capital expenditures for the Elliot Lake Laboratories. Removing the capital expenditures, it can be seen that mining expenditures rose from $3.8 million in 1985/86 to $4.6 million in 1987/88, an increase of 21 percent over the 2-year period.

Table 3.12 shows funding in the various CANMET laboratories. The figures do not correspond exactly to those in table 3.11, because they include some energy activities and omit most of the management and support funding. The severe decline in the A-base of the Mining Research Labs is misleading, again because of the capital expenditures on the Elliot Lake Lab are included in the 1985/86 figures. After adjusting for capital expenditures it is apparent that the A-base has remained stable, as it has in the other three labs.

Table 3.11 CANMET Mineral Technology Total Funding by Activity, 1985/86 - 1987/88
(1981 $ thousand)

	1985/86	1986/87	1987/88
MINING			
Mining methods & equipment	613	517	628
Rock mechanics	1,163	2,418	2,264
Mine environment	3,095	664	515
Uranium reserves assessment	244	200	104
Explosive atmospheres	474	353	515
Equipment safety certif.	343	360	356
Management and support	382	806	522
Total:	6,315	5,318	4,902
of which capital	2,499	557	279
COAL MINING AND PREPARATION			
Coal reserves assessment	356	287	185
Coal mining: west[a]	651	808	1,094
Coal mining: east[b]	1,262	1,045	1,110
Coal preparation	1,663	1,382	1,239
Coal desulpherization	678	583	706
Management and support	312	1,011	449
Total:	4,921	5,116	4,783
of which capital	855	787	741
MINERAL PROCESSING			
Minerals evaluation	467	499	549
Benefication - metallic	1,176	1,246	1,476
Benefication - ind. mineral	1,487	1,538	1,338
Treatment - ceramic	1,126	929	1,026
Treatment - ind. mineral	1,238	1,596	1,224
Biotechnology	303	281	526
Extraction - metallic	2,485	2,445	1,995
Extraction - radioactive	372	251	0
Standards and specification	826	785	819
By-product recovery	862	732	640
Environmental controls	3,020	2,086	1,012
Management and support	1,007	700	808
Total:	14,370	13,090	11,409
of which capital	773	479	504
METALS AND MATERIALS			
Development of casting processes	1,347	1,319	1,310
Development of metal work tech.	783	692	628
Weld process development	788	994	768
Non-destruct evaluation	856	842	914
Microstr. & prop. of mat.	1,230	1,034	971
Control & prevention of corrosion	1,124	986	827
Dev. & applic of adv. instr.	527	511	537
Material failure	1,047	885	1,066
Management and support	695	1,114	1,142
Total:	8,398	8,377	8,163
of which capital	618	816	734

Table 3.11 CANMET Mineral Technology Total Funding by Activity (continued)
(1981 $ thousand)

	1985/86	1986/87	1987/88
Fuels technology	21,389	20,250	18,091
of which capital	2,574	2,385	2,005
Technology information	2,038	2,124	2,176
of which capital	41	40	77
Technical services	2,526	2,509	2,022
of which capital	49	48	44
Activity management and support	4,008	3,432	4,197
of which capital	837	134	308
Canada Explosive Act admin.	559	588	690
of which capital	29	29	29
All totals	64,524	60,777	56,445
Total Capital	8,277	5,274	4,823
Total A-base	38,575	32,060	31,344

Source: Derived from CANMET Research Program Office fiscal year allocations.

[a] For 1987/88, defined as surface coal and oil sands mining
[b] For 1987/88, defined as underground coal mining.

Table 3.12 CANMET Funding by Laboratory and Activity, 1985/86 - 1987/88 (1981 $ thousand)

	1985/86	1986/87	1987/88
MINING RESEARCH LABS (MRL)			
Mining methods and equipment	368	350	484
Rock mechanics	865	985	1,282
Mine environment	2,797	528	457
Uranium reserves assessment	203	200	104
Explosive atmospheres	367	353	469
Equipment safety certification	343	360	356
Management and support	382	385	522
Environmental controls	125	125	135
Explosives technology	559	552	612
MRL total	6,010	3,838	4,421
MRL A-base total	5,869	3,543	4,162
MRL A-base capital	2,492	216	212
MRL A-base less capital	3,377	3,327	3,950
MINERAL SCIENCE LABS (MSL)			
Mine environment	134	136	0
Coal desulphurization	431	424	484
Minerals evaluation	252	259	348
Beneficiation - metallic	906	877	1,066
Beneficiation - industrial minerals	732	740	809
Treatment - ceramic	926	796	923
Treatment - industrial minerals	542	669	644
Biotechnology	303	281	333
Extraction - metallic	1,094	1,272	1,702
Extraction - radioactive	372	251	0
Standards and specifications	793	753	792
By-product recovery	515	416	466
Environmental controls	601	1,725	693
Management and support	1,007	699	808
Fluidized bed combustion	139	146	140
Development of casting processes	81	82	86
Microstr & prop adv. materials	40	39	41
MSL total	8,868	9,566	9,333
MSL A-base total	8,003	8,591	8,193
COAL RESEARCH LABS (CRL)			
Coal reserves assessment	278	185	190
Coal mining: west[a]	406	610	817
Coal mining: east[b]	948	739	827
Coal preparation	1,194	1,145	1,082
Coal desulphurization	0	0	70
Management and support	312	420	449
Bitumen/oil treatment etc.	570	556	580
Carbonization	222	222	228
CRL total	3,930	3,878	4,243
CRL A-base	2,310	2,303	2,481

Table 3.12 CANMET Funding by Laboratory and Activity (continued)
(1981 $ thousand)

	1985/86	1986/87	1987/88
PHYS. METALLURGY RESEARCH LABS (PMRL)			
Development of casting processes	1,209	1,157	1,120
Development of metal working tech.	620	551	552
Weld process development	546	456	498
Non-destruct eval. of water & strut	593	619	736
Microstr & pro of eng materials	917	870	840
Control & prevent of corro & erros	732	951	700
Devel & applic of advance instr	478	471	771
Material failure control & anal	712	663	920
Management and support	695	876	920
PMRL total	6,502	6,416	6,614
PMRL A-Base	5,584	5,509	5,523

Source: Derived from CANMET Research Program Office fiscal year allocations.

[a] For 1987/88, defined as surface coal and oil sands mining
[b] For 1987/88, defined as underground coal mining.

MINERAL DEVELOPMENT AGREEMENTS

In 1983 the federal government began discussion with each of the provinces on new Economic and Regional Development Agreements (ERDAs) to replace the General Development Agreements that expired in March 1984. Responsibility for the provincial ERDAs was assigned to the Ministry of State for Economic and Regional Development (MSERD), but that ministry ceased to exist in mid-1984, and the task was transferred to the office of Regional Development in the Department of Regional Industrial Expansion (DRIE). Equivalent agreements with the territories are administered by the Department of Indian Affairs and Northern Development. The ERDAs have been followed by 5-year sub-agreements for mineral development (MDAs) in 9 provinces (all but Alberta) and the two territories. The mineral sub-agreements are the responsibility of EMR, and focus on 3 principal areas:

- geoscience studies (federal input by the Geological Survey of Canada);
- studies in extraction and processing technology (federal input by CANMET);
- market and feasibility studies (federal input by the Mineral Policy Sector of EMR).

All the agreements identify, as their principal objective, strengthening and diversifying the mineral industry sector of the provincial economy.

Table 3.13 gives a summary of some of the major features of CANMET support in the MDAs' mining and mineral technology components. By far, Quebec has the most ambitious MDA in terms of total funding. It also has the largest mining and mineral technology component. CANMET does not have responsibility for delivery of Quebec's program, nor for the MDA's of the Territories, Prince Edward Island and British Columbia. Geoscience comprises more than 50 percent of the total funding for each province except Quebec and Prince Edward Island. The federal contributions to the Mineral and Technology components handled by CANMET are already included in the figures for CANMET presented previously, and the bulk of the remainder of the federal share is included in the Geological Survey figures in chapter 8. Table 3.14 shows the time distribution of CANMET's MDA funding by mining and mineral processing activities where available.

Table 3.13 Federal Funding of Mining and Mineral Technology (M&MT) Under the MDAs, 5-Year Cumulative Totals, Current $

Province	Time Period	Total MDA $ million	M&MT $ million	M&MT % of MDA	CANMET Share $ million	CANMET Share % of M&MT
Newfoundland	1984-89	22.0	2.1	9.5	1.5	71.4
Prince Edward Island	1986-89	0.3	0.0	0.0	0.0	0.0
Nova Scotia	1984-89	26.9	4.9	18.2	3.3	67.3
New Brunswick	1984-89	22.3	3.3	14.7	3.0	90.0
Quebec	1985-90	100.0	8.0	8.0	0.0	0.0
Ontario	1985-90	30.0	3.6	12.0	3.6	100.0
Manitoba	1984-89	24.7	7.4	30.0	4.7	63.5
Saskatchewan	1984-89	6.4	0.5	7.8	0.5	100.0
British Columbia	1985-90	10.0	0.0	0.0	0.0	0.0
Yukon	1985-90	3.9	0.6	15.4	0.05	8.3
NWT	1987-91	7.0	1.0	14.3	0.0	0.0
Total		253.5	31.4	12.4	16.7	53.2

Source: CANMET special compilations.

Note: Federal funding for the Quebec MDA is handled by EMR but not by CANMET. Most federal funding of M&MT under the MDAs in the Territories is handled by DIAND.

Table 3.14 CANMET MDA Funding by Activity, 1984/85-1990/91
(current $ thousand)

	1984/85	85/86	86/87	87/88f	88/89f	89/90f	90/91f
Mining							
Mining methods and equipment	0	102	138	223	605	132	0
Rock mechanics	58	490	1,724	1,582	881	281	39
Capital	0	260	151	90	30	0	0
Planned projects	0	0	0	0	0	356	25
Total	58	852	2,014	1,896	1,516	769	64
Mineral Processing							
Minerals evaluation	0	206	429	346	109	108	0
Beneficiation - metallic	0	142	174	370	324	0	0
Beneficiation - industrial minerals	0	164	642	396	260	102	0
Treatment - industrial minerals	0	259	740	547	404	103	0
Extraction - common metals	327	693	323	233	428	0	0
Extraction - rarer metals	0	79	75	24	10	0	0
Environmental controls	0	0	0	0	114	147	0
Capital	309	174	0	0	0	0	0
Planned projects	0	0	0	0	78	500	0
Total	636	1,716	2,382	1,917	1,727	959	0
Total	694	2,568	4,395	3,813	3,242	1,728	64

Sources: CANMET, Long-Term Plans 1988-1993, Research Program Office 1988.
Note: CANMET has responsibility for delivery of the federal share of the MDAs for six of the provinces - Newfoundland, Nova Scotia, New Brunswick, Ontario, Manitoba and Saskatchewan.

FEDERAL EXTRAMURAL SUPPORT FOR MINERAL-RELATED R&D

Federal extramural support for mineral R&D consists of grants and contracts for research, which go mainly to universities and to industry. Federal grants to universities are relatively easy to identify. However, in the case of contracts, problems may arise. Many contracts are administered by the Department of Supply and Services on behalf of EMR so that there is danger of missing some of this source of funding if DSS contracts are omitted, but a much greater possibility of double-counting if they are included. They are therefore ignored.

THE NATURAL SCIENCE AND ENGINEERING RESEARCH COUNCIL

The Natural Science and Engineering Research Council (NSERC) was established in 1978 to take over the role of the National Research Council (NRC) in distributing federal government R&D funding in science and engineering. Funding allocations are made by a large number of peer committees:

- 4 permanent, including one on grants and scholarships, and one for strategic grants;
- 4 advisory;
- various ad hoc committees (2 in 1986/87);
- 4 selection committees, including one for the Steacie Fellowships and one for university-industry grants;
- the grant, scholarship and fellowship selection committees that allocate the funding in the annual competition for research base support.

There are 18 discipline-based peer committees in the latter group, plus an additional 7 for various interdisciplinary or cross-disciplinary purposes, such as publications and university research fellowships. Each of the Strategic Grant categories has a selection committee as well.

NSERC's programs are divided into four planning elements:

- the research base;
- scholarships and fellowships;
- targeted research;
- general support.

Total funding for these four elements plus administration from 1980/81 to 1986/87 is shown in table 3.15. NSERC's expenditures increased by 41 percent over this period with an average annual increase of 6 percent per year. Expenditure growth was strong in the first part of the period but in 1985/86 expenditures fell, and in 1986/87 they increased only marginally.

The research base, with funding allocated by the discipline-based peer committees, offers a variety of grants:

- operating, individual and team;
- northern supplement (merged with operating in 1986);
- equipment grants, minor and major;
- infrastructure grants;
- collaborative special projects;

Table 3.15 NSERC Expenditures by Activity[a], 1980/81 - 1987/88
(1981 $ million)

	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88
Research base	122.0	134.4	147.0	155.0	149.6	154.0	156.1	157.7
Scholarships and fellowships	21.8	27.3	32.1	38.4	43.8	44.9	43.1	41.2
Targeted research	21.4	23.4	26.4	33.9	39.2	36.4	39.6	41.0
General research support	10.7	11.9	13.8	13.0	21.3	8.9	6.1	12.6
Total program	176.1	197.0	219.2	240.3	253.8	244.3	244.9	252.6
Administration	3.8	4.1	5.2	5.8	9.3	9.2	9.3	9.2
Total expenditures	179.9	201.1	224.4	246.0	263.1	253.4	254.2	261.8

Source: NSERC Report of the President, 1987/88.

a Adjusted to conform to NSERC's new activity structure.

Table 3.16 NSERC Operating, Equipment and Infrastructure Grants by Committee, 1987/88
(current $ thousand)

Grant Selection Committee	Operating	Equipment	Infrastructure	Total	As % of Total
Biology	41,926	3,998	619	46,544	24.3
Psychology	7,293	515	179	7,988	4.2
Chemistry	17,060	4,006	646	21,772	11.4
Physics, space astronomy	25,775	2,008	4,783	32,565	17.0
Chemical and metallurgical engineering	9,528	1,485	578	11,591	6.0
Civil engineering	9,412	850	505	10,767	5.6
Electrical engineering	9,455	1,369	319	11,143	5.8
Mechanical engineering	8,462	1,139	125	9,726	5.1
Industrial engineering	2,558	61	63	2,682	1.4
Earth sciences	11,461	1,755	782	13,997	7.3
Computing and information science	7,363	1,235	878	9,475	4.9
Pure and applied mathematics	6,429	160	77	6,486	3.4
Statistical sciences	2,110	129	250	2,489	1.3
Interdisciplinary	683	130	199	1,012	0.5
Subtotal	159,337	18,898	10,03	188,237	98.2
Committee on grants and scholarships	0	3,365	0	3,365	1.8
Total	159,337	22,262	10,003	191,602	100.0
Total (1981 $)	123,326	17,231	7,742	148,299	

Source: NSERC, Report of the President, 1987/88.

- new research initiatives.

Applications for R&D in mining have been handled mainly by the Civil Engineering Committee, which has had a mining representative only since 1986. Metallurgy is combined with Chemical Engineering. The distribution of funds by the various discipline-based committees for operating, equipment and infrastructure grants for the year 1986/87 is shown in table 3.16 in current dollars, with the total deflated to 1981 dollars for comparison with other tables. Table 3.17 shows NSERC operating grants (excluding equipment and infrastructure) by primary area of application for the years 1980/81 and 1986/87.

Table 3.17 NSERC Operating Grants by Area of Application[a], 1980/81 and 1987/88
(1981 $ million and percent of total

	1980/81		1987/88		% Change 1980/81 - 1987/88
	$	%	$	%	
Agriculture[b]	7.8	8.5	9.4	8.3	20.5
Energy	5.4	5.9	6.7	5.9	24.1
Environment	2.9	3.2	4.6	4.0	58.6
Earth sciences[c]	5.3	5.8	5.5	4.8	3.8
Health	3.9	4.2	7.5	6.6	92.3
Construction	3.7	4.0	5.1	4.5	37.8
Social development and services	1.4	1.5	3.5	3.1	150.0
Industrial development	7.0	7.6	12.6	11.1	80.0
Transport and telecommunications	2.4	2.6	3.9	3.4	62.5
Space and aeronomy	1.0	1.1	1.1	1.0	0.0
Northern development	0.6	6.5	0.8	0.7	33.3
General advancement of knowledge	48.1	52.3	52.0	45.8	8.1
Not reported	1.6	1.7	1.0	0.9	-37.5
Total	91.9	100.0	113.6	100.0	23.6

Source: NSERC, Report of the President, 1980/81 and 1987/88.
[a] excludes project grants.
[b] including fisheries, forestry and food.
[c] the solid earth, hydrosphere and atmosphere.

Tables 3.18 and 3.19 show the peer and strategic grants coded to mining and metallurgy from 1980/81 to 1986/87. Athough the growth rates are fairly equal over the period shown, it is apparent that the per capita grants in metallurgy are much higher, and the number and types of grants given is much greater. These grants are discussed further in chapter 7.

Table 3.18 NSERC Mining Grants, 1980/81 - 1986/87
(1981 $ thousand)

Grant Type	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87
Peer Grants:							
Operating grants[a]	89	101	51	89	111	183	163
Equipment grants[b]	-	-	-	76	233	-	-
Mining total	89	101	51	165	344	183	163
Average size of grant	13	9	10	17	29	10	10

Source: NSERC special compilation.
Note: peer grants only: no strategic grants were reported for mining code 4700.
[a] Individual grants only.
[b] Major and minor equipment.

Table 3.19 NSERC Metallurgy Grants, 1980/81 - 1986/87
(1981 $ thousand)

Grant Type	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87
Peer Grants							
Operating[a]	1,827	1,947	2,108	2,349	2,479	2,538	2,393
Equipment and infrastructure[b]	285	1,402	1,478	1,632	1,028	1,283	1,249
Total:	2,112	3,349	3,586	3,981	3,507	3,821	3,642
Average size of grant	17	23	25	27	25	29	27
Strategic Grants Total	479	493	425	823	1,206	1,513	1,312
Metallurgy Total	2,591	3,842	4,011	4,804	4,713	5,334	4,954

Source: NSERC special compilations.
[a] includes conference, individual, team, travel and cooperative grants.
[b] includes individual, team, and minor equipment grants.

General research support, the fourth element in NSERC's funding program, shown in table 3.15 consists mainly of grants given to university presidents, in proportion to the research grants received by their respective institutions; this portion cannot be classified by discipline.

Table 3.20 shows the number and value of research fellowships granted by NSERC in the 1980/81 to 1986/87 period. No fellowships were granted in mining. An average of about 2.5 percent of the total value of fellowships was allotted to metallurgy. Table 7.12 presents more information on scholarships and fellowships awarded.

Table 3.20 NSERC University Research Fellowships[a] by Field of Research, 1980/81 - 1986/87
(1981 $ thousand and number)

Field	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87
Value							
Metallurgy	22.2	42.0	56.0	90.6	115.9	102.9	71.5
Mining	0	0	0	0	0	0	0
Total NSERC fellowships	932.2	1,921.1	2,619.1	3,474.3	4,039.4	3,503.7	3,573.3
Number							
Metallurgy	2	4	5	7	8	7	4
Mining	0	0	0	0	0	0	0
Total NSERC fellowships	93	208	258	264	304	281	262

Source: NSERC special compilation.

[a] Includes basic grants, supplements and individual university research fellowship operating grants, in the fiscal year in which they were paid.

EMR Research Grants

EMR provides R&D funding each year for earth sciences, energy, and mining and minerals, as shown in tables 3.21 and 3.22. The largest category is earth sciences, with an average of 47 percent of the total funding over the 1980-1987 period. EMR's grant program is not large, relative to NSERC's funding. For example, funding by EMR for the earth sciences in 1986 represented only about 5 percent of the level of earth sciences R&D support provided by NSERC in 1986/87 and about the same percent for mining and minerals.

Table 3.21 EMR Research Grants, 1980-1987
(1981 $ thousand)

Sector	1980	1981	1982	1983	1984	1985	1986	1987
Earth sciences	648	655	602	573	553	535	521	500
Energy	449	520	478	455	439	425	337	311
Mining and minerals	266	223	205	195	188	182	254	257
Total	1,362	1,398	1,284	1,223	1,181	1,142	1,111	1,067

Source: EMR External Research Program, 1987-88 Update of Statistics: Research Agreements Program.

Table 3.22 EMR Research Grants, 1980-1987
(percent of total)

	1980	1981	1982	1983	1984	1985	1986	1987
Earth sciences	47.6	46.9	46.9	46.9	46.9	46.9	46.9	46.9
Energy	33.0	37.2	37.2	37.2	37.2	37.2	30.3	29.1
Mining and minerals	19.5	16.0	16.0	16.0	16.0	16.0	22.8	24.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: table 3.21.

CONCLUSION

Federal support for mineral-related R&D is derived chiefly from CANMET, as shown in table 3.23. The A-base of CANMET has fallen in current dollar terms since 1985/86 (table 3.9), but is forecast to decline in real terms to 1990/91. The approaching termination of the MDAs and uncertainty over the future of the Energy R&D program suggests that significant real cuts in the present level of federal mining and mineral R&D will result.

The total figure of over $37 million (1981 $) in 1986/87 represents about 0.25 percent of mining and primary metal GDP of $15 billion (1981 prices) in 1986 as shown in table 2.4. For mining alone, the federal R&D expenditures represent less than 0.1 percent of the value of mine production as shown in table 2.2. Metallurgy R&D expenditures represent about 0.48 percent of primary metals GDP as shown in table 2.4.

Table 3.23 Summary of Federal R&D Support for Mining and Metallurgy, 1986/87

	Current $ Thousand	1981 $ Thousand	% of Total
Mining			
CANMET[a]	13,128	10,436	27.7
Quebec MDA[b]	500[e]	397[e]	1.0
NSERC[c]	205	163	0.4
EMR grants[d]	160	127	0.3
Total	13,993	11,123	29.5
Metallurgy			
CANMET[e]	27,005	21,467	56.9
NSERC[f]	6,323	5,026	13.3
EMR grants[d]	160	127	0.3
Total	33,488	26,620	70.5
Mineral total	47,481	37,743	100.0

[a] table 3.6, mining plus coal mining preparation.
[b] estimate based on personal communication, EMR, January 1988. Federal funds, but program delivery is by Quebec.
[c] table 3.18, total.
[d] table 3.21, half of mining and minerals in 1986.
[e] table 3.6, mineral processing plus metals and materials.
[f] table 3.19, total, plus table 3.20.

4. PROVINCIAL GOVERNMENT SUPPORT FOR MINERAL R&D

IN-HOUSE PROVINCIAL R&D ACTIVITIES

The provincial governments have primary responsibility for development of mineral resources within their jurisdiction, and have in some cases required or encouraged processing of metallic minerals beyond the concentrate stage before shipment out-of-province. The provincial governments are also responsible for environmental regulation, including regulation of water quality from mines, mine waste and tailings, and of smelter emissions.

For some provinces, particularly Newfoundland, Saskatchewan, and the Territories (see table 2.6), minerals represent a significant percent of provincial GDP. Nevertheless, provincial governments have shown relatively little interest in conducting in-house mining and mineral-related R&D, either for productivity improvement or for environmental and health protection. The major exception is Quebec, which has the lowest economic dependence on the mineral industry next to PEI but which nevertheless has a provincial organization devoted entirely to mineral R&D, le Centre de Recherches Minérales. In addition, some in-house provincial R&D on mineral processing is funded by New Brunswick in its Research and Productivity Council. Coal R&D is conducted at Devon, Alberta, where the Alberta government has research facilities along with those of the federal government and industry.

Province-by-province information on mineral-related R&D is presented in the following section.

Alberta

Alberta has extensive programs of R&D support in energy, as well as its own in-house facilities in the Alberta Research Council. Funding assistance and joint R&D programs include:

- Coal Research and Technology Program - a funding program for research in enhancing the province's competitive position in coal production, in minimizing the environmental impact of mining, and in new uses for coal;

- financial support for the Coal Mining Research Centre - a private corporation for applied research in mining, beneficiation, and health and safety aspects of coal mining;

- a proposed Coal Reclamation Research Program - a government/industry research program.

Table 4.1 shows the extent of provincial support via the Alberta Research Council for the Coal Research and Technology Program. Provincial funding information for the other R&D programs was not provided.

Table 4.1 Contributions of the Alberta Research Council to the Coal Research and Technology Program, 1981/82 - 1987/88 (1981 $ thousand)

1981/82	666
1982/83	1,325
1983/84	1,213
1984/85	1,340
1985/86	1,658
1986/87	1,707
1987/88	1,536

Source: Alberta Research Council, private communication, July 1988.

British Columbia

B.C. in-house programs are small, and mainly in the Mineral Policy and Evaluation Branch of the department of Energy, Mines and Petroleum Resources, involving marketing studies and minehead financial simulation studies. Small amounts of financial assistance have also been provided for extramural R&D projects including coal liquefaction, silver catalyzed biological leaching of copper concentrates, and coal oxidation. The Mineral Development Agreement negotiated by B.C. includes $1.6 million for "mine development and engineering studies", but it does not have a "Mining and Minerals Technology" component.

Manitoba

Manitoba's in-house programs are mainly tied to the provincial share of the Canada/Manitoba Mineral Development Agreement, with an emphasis on processing technology. Funding levels for the mineral and technology components of the MDAs for all provinces are given in the following section in table 4.5, and in tables 3.13 and 3.14 in chapter 3.

New Brunswick

In-house programs in New Brunswick, funded under the Canada/New Brunswick Agreement Technology program, involve mainly the New Brunswick Research and Productivity Council's R&D interests in extractive metallurgy. The New Brunswick Research and Productivity Council (RPC) has been engaged for some years in a major project on recovering base metals from ores. Funding for the project has been 80 percent federal and 20 percent provincial. The annual reports provide a breakdown of RPC expenditures on this project up to 1982/83, as shown in table 4.2 along with estimates based on information in the reports for the subsequent years. The surge in expenditures in the mid 1980s reflects services performed for a federally-funded plant for leaching of sulphide ores.

Table 4.2 New Brunswick Research and Productivity Council Mineral Processing R&D Expenditures 1980/81 - 1987/88 (1981 $ thousand)

	Total	New Brunswick Contribution
1980/81	461	92
1981/82	476	95
1982/83	587	117
1983/84	1,050	210
1984/85	1,014	203
1985/86	980	196
1986/87	954	191
1987/88	774	155

Source: New Brunswick Research and Productivity Council, private communication, June 1988.

Ontario

In-house R&D programs in Ontario were formerly located in the Ontario Research Foundation (ORF), a provincial research organization which accepted contracts from industry on a confidential basis. It was renamed ORTECH and privatized in 1988. Mineral research has been mainly in the processing field. However, the funding is now derived entirely from contracts, and the only provincial funds included in the mineral processing activities are in the form of contracts, for example from the Ministry of Energy.

R&D assistance programs in Ontario include the Resource Diversification and Development Program which provides funding for studies and demonstration projects in resource extraction, processing and (rock mechanics) marketing, and contributions to university research chairs in mining at the University of Toronto, Laurentian University and Queen's University. Ontario also supports the tripartite rockburst project, providing 1/3 of the estimated $4.2 million that will be required over 5 years, 1985 to 1990. The Department of Labour supports and conducts R&D in the field of mine safety.

Quebec

In-house programs in Quebec are concentrated in the Centre de Recherches Minérales (CRM). As noted above, it is the only provincial government research organization exclusively for mining and minerals. It was established in 1969 to support university and industry mineral-related research. Projects may be proposed by eligible companies and conducted by CRM, which bears 70 percent of the costs. Gold is a major area of interest, as well as iron ore, industrial minerals and base metals.

CRM expenditures and revenues recovered from clients are shown in table 4.3 for fiscal years 1980/81 to 1987/88.

The second major focus in Quebec is in its R&D assistance programs, with an emphasis on asbestos. The Canada/Quebec Mineral Development Agreement includes $4 million for asbestos R&D. Other programs include:

- the ad hoc Assistance Program for Techno-Economic Studies;
- Program of Assistance for Technological Development of the Mining Industry Through the Hiring of Specialists;
- investment assistance for research laboratories.

Table 4.3 Ministère de l'énergie et des ressources
Centre de Recherches Minérales
Budget Expenditures and Contract Revenues, 1980-1988
(1981 $ thousand)

	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88
Budget Expenditures								
DAM	1,711	2,080	2,025	2,314	2,449	2,223	1,926	1,908
DRM	3,281	2,975	3,155	4,574	3,104	3,054	2,922	2,922
STM[a]	0	0	0	486	773	670	900	991
Total	4,992	5,055	5,180	7,374	6,326	5,947	5,748	5,821
Contract Revenues[b]								
DAM	0	0	18	24	48	86	67	193
DRM	0	0	132	208	369	461	574	615
STM	0	0	0	10	47	77	128	137
Total	0	0	150	241	464	624	769	944

Source: Centre de Recherches Minérales, internal document.
[a] created during fall 1982.
[b] contract revenues are amounts paid by mineral enterprises towards the costs of their projects.

DAM: Mineral Analysis Division.
DRM: Metallurgical Research Division.
STM: Mining Technology Service.

MINERAL DEVELOPMENT AGREEMENTS

Mineral Development Agreements have been signed with 9 provinces and both territories since 1983, and most include a mining and mineral technology component as noted in chapter 3. The costs of this component may be shared by the two levels of government; the provincial shares are shown in table 4.4. Program delivery may also be shared, with CANMET delivering the federal share (except for Quebec and much of the program in the Territories) mainly through contracting-out activities, and various delivery mechanisms including contracting-out for the provincial share.

Table 4.5 gives details of CANMET's mining and mineral technology expenditures by province, activity, and year. Although these numbers refer to the federal totals given in table 3.14, they are a close and in some cases an exact indication of the areas of interest identified by each province, and of the level of the provincial financial support by activity and year.

Table 4.4 Provincial Funding of Mining and Mineral Technology (MT&T) Components of MDAs, 5-Year Cumulative Totals, current dollars

Province	Time Period	Total MDA	M&MT		Provincial Share	
		$ million	$ million	% of MDA	$ million	% of M&MT
Newfoundland	1984-89	22.0	2.1	9.5	0.6	28.6
Prince Edward Island	1986-89	0.3	0.0	0.0	0.0	100.0
Nova Scotia	1984-89	26.9	4.9	18.2	1.6	32.7
New Brunswick	1984-89	22.3	3.3	14.7	0.3	10.1
Quebec	1985-90	100.0	8.0	8.0	4.0	100.0
Ontario	1985-90	30.0	3.6	12.0	0.0	0.0
Manitoba	1984-89	24.7	7.4	30.0	2.7	36.5
Saskatchewan	1984-89	6.4	0.5	7.8	0.0	0.0
British Columbia	1985-90	10.0	0.0	0.0	0.0	0.0
Yukon	1985-90	3.9	0.6	15.4	0.2	33.3
NWT	1987-91	7.0	1.0	14.3	0.5	50.0
Total		253.5	31.4	12.4	10.0	31.8

Source: CANMET special compilation, August 5, 1988.

Table 4.5 CANMET Share of MDA Mining and Mineral Technology Funding, by Province and Activity. (current $ thousand)

	1984/85	1985/86	1986/87	1987/88[f]	1988/89[f]	1989/90[f]	1990/91[f]
NEWFOUNDLAND							
Mineral Processing:							
Minerals evaluation	0	95	199	153	0	0	0
Beneficiation-metallic	0	142	130	235	315	0	0
Treatment-industrial minerals	0	0	37	45	44	0	0
Extraction - rare minerals	0	0	0	24	0	0	0
Planned projects	0	0	0	0	0	81	0
Total	0	237	366	458	359	81	0
Nfld. Total	0	237	366	458	359	81	0
NOVA SCOTIA							
Mining:							
Planned projects	0	0	0	0	0	80	0
Total	0	0	0	0	0	80	0
Mineral Processing:							
Beneficiation-metallic	0	0	20	103	0	0	0
Beneficiation-industrial minerals	0	73	344	219	260	102	0
Treatment-industrial minerals	0	139	434	377	244	103	0
Extraction - rarer metals	0	79	75	0	0	0	0
Capital	309	174	0	0	0	0	0
Planned projects	0	0	0	0	0	141	0
Total	309	464	872	699	504	347	0
N.S. Total	309	464	872	699	504	427	0
NEW BRUNSWICK							
Mining:							
Methods & equipment	0	102	138	223	605	132	0
Planned projects	0	0	0	0	0	129	0
Total	0	102	138	223	605	261	0
Mineral Processing:							
Minerals evaluation	0	76	188	106	28	0	0
Treatment - industrial minerals	0	110	253	124	115	0	0
Extraction-common metals	215	53	0	0	0	0	0
Extraction-rarer metals	0	0	0	0	10	0	0
Environmental controls	0	0	0	0	114	147	0

Table 4.5 CANMET Share of MDA Mining and Mineral Technology Funding by Province and Activity (continued)
(current $ thousand)

	1984/85	1985/86	1986/87	1987/88[f]	1988/89[f]	1989/90[f]	1990/91[f]
Planned projects	0	0	0	0	0	130	0
Total	215	239	442	231	268	277	0
Total	215	341	580	454	873	537	0
ONTARIO							
Mining:							
Rock mechanics	0	48	1,021	1,034	571	281	39
Capital	0	260	151	90	30	0	0
Planned projects	0	0	0	0	0	0	25
Total	0	308	1,172	1,124	601	281	64
Ontario total	0	308	1,172	1,124	601	281	64
MANITOBA							
Mining:							
Rock mechanics	58	443	669	445	310	0	0
Planned projects	0	0	0	0	0	147	0
Total mining	58	443	669	445	310	147	0
Mineral Processing:							
Minerals evaluation	0	34	42	87	80	108	0
Beneficiation-metallic	0	0	25	32	10	0	0
Beneficiation-industrial minerals	0	52	157	56	0	0	0
Treatment-industrial minerals	0	10	16	0	0	0	0
Extraction-common metals	112	640	323	233	428	0	0
Planned projects	0	0	0	0	0	147	0
Total	112	737	562	409	518	255	0
Manitoba total	170	1,180	1,231	854	828	402	0
SASKATCHEWAN							
Mining:							
Rock mechanics	0	0	34	103	0	0	0
Total	0	0	34	103	0	0	0
Mineral Processing:							
Beneficiation-industrial minerals	0	39	140	121	0	0	0
Planned projects	0	0	0	0	78	0	0
Total	0	39	140	121	78	0	0
Sask. Total	0	39	174	224	78	0	0

Source: CANMET Long Term Plans 1988-1993, Research Program Office, 1988.
Note: The Quebec M&MT program is not delivered by CANMET, so it is not included here.

CONCLUSION

Except in Quebec, provincial support for mining and mineral-related R&D has been very small, and largely triggered by the Mineral Development Agreements, which expire in 1990/91. Although reliable figures for total provincial expenditures are difficult to obtain, estimates for the 1986/87 total provincial expenditures are shown in table 4.6.

It should be noted that 1986/87 was the peak year for MDA expenditures, which will drop to almost zero by 1990/91. It is not clear what effect this will have on provincial contributions to mineral R&D funding. Even with the MDA-inspired provincial expenditures in 1986/87, the provincial total amounts to only about 23 percent of the federal total, and about 27 percent of CANMETs total mineral-related R&D expenditures (see table 3.22).

Table 4.6 Summary Estimates of Provincial Mineral-Related R&D Expenditures, 1986/87

	Current $ Thousand	1981 $ Thousand
Nfl. MDA	147	117
Nova Scotia MDA	422	335
New Brunswick MDA	58	46
RPC	240	191
Quebec MDAa	500e	397e
CRM	6,264	4,979
Ontario MDA	0	0
Other	na	na
Manitoba MDA	708	563
Saskatchewan MDA	0	0
Alberta ARC Coal R&D	2,148	1,707
Total provincial MDA	1,835	1,459
Other	8,652	6,878
Total provincial	10,487	8,336

Source: Tables 4.1, 4.2, 4.3, 4.4 and 4.5.
a estimate based on personal communication, EMR, January 1988. MDA contribution may be included, all or in part, in CRM expenditures.
Note: MDA funding is derived by multiplying the 1986/87 CANMET MDA expenditure for each province from table 4.6 by the ratio of the provincial/CANMET share.
eg. Newfoundland: CANMET expenditure 366 ÷ CANMET's share .714 = 512.6. 512.6 x Newfoundland's share .286 = 146.6.

5. INDUSTRY SUPPORT FOR MINERAL-RELATED R&D

INTRODUCTION

R&D in mining and metallurgy in the private sector is generally carried out by 3 principal groups:

- mining and/or smelting and refining companies;
- mining and metallurgical equipment manufacturers;
- consulting and contracting firms.

In Canada, however, there are very few domestic manufacturers of mining and metallurgical equipment. What equipment is manufactured here is almost all produced by branch plants of foreign-owned firms, which do their R&D in the countries in which they are based. The third group, consulting and contracting firms, with very few exceptions, do no R&D in Canada. Consequently, this chapter will focus on the R&D activities of mineral producing companies. A few comments on the other two groups of firms are included in the organizational description that follows.

ORGANIZATION OF THE MINERAL INDUSTRY

This section describes the organization of the mineral industry in Canada, including concentration, size of firms, degree of integration, and foreign ownership. These characteristics are significant in examining R&D funding, both for the level of R&D expenditures and for data availability. For example, industry R&D tends to be concentrated in the larger vertically-integrated firms. Therefore, examination of R&D expenditures by individual firms (where published in the annual reports) for commodities where concentration of ownership is high gives a good approximation of total R&D expenditures by commodity. On the other hand, high concentration increases the likelihood that Statistics Canada will not be able to provide commodity or sector-specific data, for reasons of confidentiality. For commodities for which production is less concentrated and firms are small, there is relatively little R&D performed or data available.

Some information is provided in this section on the R&D activities of consulting firms and equipment manufacturers, rather minor R&D players. The major industrial players' R&D activities are described in the following sections, drawing on Statistics Canada aggregate data and on data for a few of the larger mineral firms that have made such information available.

Table 5.1 provides a summary profile of the Canadian mineral industry.

Table 5.1 Profile of the Canadian Mineral Industry, 1985 (Mineral Manufacturing) and 1986 (Mining), Total Activities

	Establishments (number)	Employees (thousand)	Value of Production[a] (1981 $ million)	Value Added (1981 $ million)
MINING				
Metals				
Ni/Cu/Zn	25	21.4	2,716	1,396
Gold	47	8.7	1,110	813
Uranium	5	5.6	831	645
Iron	8	6.4	1,024	567
Ag/Pb/Zn	13	4.1	777	324
Misc.	7	1.2	97	52
Total	105	47.3	6,550	3,798
Industrials				
Potash	11	4.3	483	322
Asbestos	5	3.2	200	126
Other	354	9.5	1 907	665
Total	370	17.0	1,590	1,113
Total nonfuel mining	475	64.3	8,140	4,911
NON-FUEL MINERAL MANUFACTURING				
Primary metals				
Smelting & refining	30	30.6	3,755	1,799
Iron & steel	200	61.4	7,916	3,239
Other	205	14.8	2,194	715
Total	435	106.8	13,865	5,753
Nonmetallic	1,532	50.6	4,803	2,592
Total nonfuel mineral manufacturing	1,967	157.4	18,668	8,345

Source: EMR, Canadian Mineral Industry Monthly Report, September and October 1987.

[a] Value of production applies to mining only. For nonfuel mineral manufacturing, the numbers given are for value of shipments.

Note: Coal mining is not included in this profile.

Mining Companies

Canadian mining companies include a small group of producing companies that are large, well-known, and account for most of Canada's mineral production. These companies, most of them multinationals, are vertically integrated into activities that can include everything from exploration to new materials. Some have diversified into other resources and other industrial sectors. In addition, there is a much larger number of smaller companies, making up the 200 or so producers that operate Canada's 300 or so mines.

Ontario had the largest number of producing mines in 1984, with 52, followed closely by Quebec with 48. By commodity, coal mines were the largest group, at 45 mines. Twenty-one of them are in Alberta, where most of the coal is used for electrical generation within the province, generally right at the minesite. Gold production was spread across 5 provinces, with 40 mines, and copper mines were equally widespread. Nickel and uranium were more limited in terms of geographic dispersion, each with production in only 2 provinces, and 14 and 7 mines respectively.

Customers for the products of the industry are world-wide. Products are sold in crude form such as ores and concentrates, as refined metal, and in fabricated forms. With minor exceptions, these products are perceived to be commodities, and little product differentiation is possible, so that competition is largely on the basis of price. Under these conditions, the state of the market is determined by the relative power of buyers and sellers. When there is over-supply, as has been the case from time to time for many of Canada's mineral products in recent years, customers can dictate contract terms, and the producers must rely mainly on cost control to maintain their competitive position.

The producers also have economic linkages to a variety of manufacturing, service, and supply companies that are partially or totally dependent on the industry for their prosperity. Some of these firms supply specialized services, such as exploration, construction, or mine engineering consulting. Others may provide more general services, such as machine shops, foundries, and distribution agencies, but are located in the many communities throughout Canada which are greatly dependent on the mining industry for their survival.

Table 5.2 shows the number of corporations in various sectors of the mineral industry, along with aggregate financial information for 1985. On average, metal mining firms are the largest in terms of total assets (excluding petroleum). "Other mining" includes a great many small firms

Table 5.2 Corporations and Aggregate Financial Statistics in the Canadian Mineral Sector, 1985

	No. of Corporations	Assets ($ million)	Sales ($ million)	Profits ($ million)
Mining				
Metal mines	225	26,531	10,089	103
Mineral fuels[a]	2,453	82,759	32,181	9,418
Other mining[b]	5,119	12,118	6,006	-93
Total mining	7,797	121,408	48,276	9,428
Mineral Manufacturing				
Primary metal products	418	17,673	14,236	164
Nonmetallic mineral products	1,587	8,138	6,696	749
Petroleum & coal products	131	39,166	35,702	2,495
Total mineral manufacturing	2,136	64,977	56,634	3,408

Source: EMR, Canadian Mineral Industry Monthly Report, June 1988.
[a] includes petroleum and natural gas as well as coal. There are about 17 coal producers in Canada.
[b] includes junior mining and mining services.

such as junior mining companies, consultants, and contractors. In the description that follows, attention is focused on mining companies, i.e. companies that mine deposits and produce minerals in crude form such as concentrate. A subset of these companies also is engaged in smelting and in refining.

Concentration of Ownership

Concentration of ownership (measured in terms of share of total production) among the owners of the 300 or so producing mines varies widely, according to the minerals produced. A major determinant of concentration of ownership has been the geological characteristics of the deposits, chiefly size and richness. Least concentrated is the building materials sector, with many low-value, high-bulk operations scattered across the country and generally serving local markets. Ownership in lode gold mining is also fairly widespread, since the deposits tend to be fairly small, with relatively small capital requirements.

In potash, uranium and asbestos a considerable degree of concentration has evolved, partly because of large deposits but also because each is produced largely in one province (Saskatchewan for potash and uranium; Quebec for asbestos) where the provincial governments have

acquired a strong ownership or control position. Not surprisingly, it is in these three commodities that the greatest Canadian producer cooperation in R&D has been found.

The base metals sector has tended to have a high degree of concentration of ownership, particularly for nickel and lead/zinc. This is in part due to the existence of a few very large and rich deposits, such as the Sullivan Mine, Cominco's lead/zinc/silver mine which has been in production since 1908; Inco's Sudbury and Thompson nickel holdings; and the more recent Kidd Creek lead/zinc deposit, which has also created an industry leader. Another factor which has increased concentration of ownership in these metals is the size of the capital investment required to develop these very large deposits and process the ore. In 1983, for nonferrous metals, there were 130 mines and 88 concentrators or mills managed by 68 companies. Of the 130 mines (which ranged in capacity from 40,000 to 29 million tonnes of ore per year), the 10 largest produced more than half the total tonnage.[1] Concentration has become even greater with the recent takeovers of Kidd Creek (by Falconbridge) and Cominco (by Teck).

In copper, ownership has been somewhat more widespread, largely due to the existence of a number of relatively small and high-grade copper mines in Quebec. British Columbia copper mines on the other hand are much larger porphyry deposits, with fairly low grades and requiring large investments for development.

The base metal mining firms are also major producers of precious metals, chiefly as byproducts of their base metal operations. Recently, a number of base metal firms have expanded into lode gold mining as well, to protect themselves against weaknesses in base metal markets and prices.

Ownership of both iron ore and asbestos is highly concentrated. In iron ore, with 9 operations and 8 companies in 1983, the three largest mines produced over 75 percent of the contained iron, and 1 company produced over 40 percent. For asbestos, the 2 largest mining and concentrating operations produced almost half of the total asbestos fibre.

Size of Mining Firms

Asset size in Canadian companies is determined in part by the size of deposit being mined and by the scale of the resulting operation. Increasing concentration through horizontal integration in mining (i.e., ownership of a number of producing mines) is another factor in determining asset size. Generally, underground mining firms tend to be smaller in terms of asset size than open-pit firms, although the three mentioned

1. EMR, Canadian Mines: Perspective from 1984, (Ottawa: 1985)

above, (Cominco, Inco, and Kidd Creek) have been exceptions to this rule because of exceptionally large deposits.

Table 5.3 shows the number of corporations by asset-size class over the period 1979-85 for the metal mining industry as a whole. Table 5.4 demonstrates forcefully that "other mining", which includes junior mining and mining services, includes a very large group of small firms.

Only the largest half-dozen or so firms in the mineral industry, all of which have assets over $1 billion and are vertically integrated producers (see below), have major R&D programs. The rest of the industry has to rely chiefly on purchase and transfer of new technology from outside sources in order to realize major innovation opportunities.

Table 5.3 Number of Corporations by Asset Size, Metal Mining Industry, 1979-1985

	Asset Size Class ($ million)			
	under 10	10-24.9	25 and over	Total Number of Firms
1979	53	16	55	124
1980	65	16	57	138
1981	100	23	63	186
1982	98	21	55	174
1983	72	18	55	145
1984	na	na	60	245
1985	na	na	56	225

Source: Statistics Canada, 61-210.

Table 5.4 Number of Corporations by Asset Size, Other Mining, 1979-1985

	Asset Size Class ($ million)			
	under 10	10-24.9	25 and over	Total Number of Firms
1979	3,530	49	58	3,637
1980	3,983	67	63	4,113
1981	4,579	66	74	4,719
1982	4,738	70	73	4,881
1983	4,105	67	72	4,244
1984	na	na	69	5,086
1985	na	na	68	5,119

Source: Statistics Canada, 61-210.

Foreign Control in the Mining Sector

Foreign control of nonfuel mineral industry assets has fallen significantly since 1969, as shown in table 5.5. The 1981 figure, at 30 percent, is much lower than that for petroleum, which was 60 percent. The core of the industry, metal mining, shows the highest percent of Canadian control, according to the EMR figures in table 5.6. Past history suggests that R&D expenditures have fallen in the nonferrous metal mining sector at the same time that Canadian ownership has increased. This appears to be in conflict with conventional wisdom, which generally holds that foreign ownership inhibits domestic R&D activities. Convention wisdom does seem to apply in the case of iron ore, where foreign ownership is high and R&D intensity is relatively low.

Table 5.5 Foreign Control of Nonfuel Mining Sector (Assets), 1969-1985

Year	Foreign Control (percent of sector)
1969	60.2
1970	62.3
1971	62.3
1972	48.2
1973	47.4
1974	46.7
1975	46.7
1976	44.4
1977	42.1
1978	39.3
1979	38.1
1980	33.9
1981	30.1
1982	30.4
1983	28.0
1984	23.5
1985	17.7

Source: Statistics Canada 61-210.
Note: 1969-81 excludes coal and iron and steel mills, includes uranium; 1982-85 is for metal mining only.

The Smelting and Refining Sector

In Canada there are 8 major nonferrous metal mining companies which are vertically integrated into smelting and refining: Inco, Noranda, Brunswick Mining and Smelting, Falconbridge, Sherritt Gordon, Hudson Bay

Table 5.6 Foreign Control[a] of Firms in the Mining and Mineral Manufacturing Industries, 1976, 1982 and 1985.
(percent)

	Corporations			Assets			Sales			Profits		
	1976	1982	1985	1976	1982	1985	1976	1982	1985	1976	1982	1985
Mining												
Metal mines	23.2	22.7	13.3	40.9	23.1	17.7	45.3	30.3	26.0	25.5	61.4	7.8
Mineral fuels	24.3	14.0	8.6	67.3	38.3	37.7	83.0	58.8	58.0	80.9	69.5	67.6
Other mining (including mining services)	6.9	4.7	3.6	55.4	34.5	25.2	54.5	35.6	31.4	80.6	221.0	9.7
Total mining	12.0	7.3	5.5	54.9	34.1	32.1	66.4	49.6	48.0	67.8	72.3	67.5
Mineral Manufacturing												
Primary metal products	45.8	11.4	10.0	79.7	14.3	20.2	77.1	16.7	16.8	85.6	3.3	45.7
Nonmetallic mineral prod.	42.5	5.5	4.5	29.9	73.7	70.8	38.7	57.1	54.9	31.8	56.9	71.4
Petroleum and coal prod.	35.3	21.8	16.8	na	59.9	42.1	na	77.6	57.4	na	66.4	46.7
Total mineral manufacturing industries	43.2	7.3	6.3	na	49.5	39.7	na	60.5	46.9	na	74.1	52.1

Source: EMR, Canadian Minerals Yearbook, 1978 and 1987; Canadian Mineral Industry Monthly Report, June 1988.

[a] A foreign corporation is defined as having 50% and over nonresident ownership.

Mining and Smelting, Alcan, and Cominco.[2] Most have a number of producing mines supplying their further processing operations. All of them are world-scale operations. For example, Inco and Falconbridge are the first and second ranked nickel producers in the world. Noranda and Cominco Ltd. rank first and second in the production of zinc. Alcan is the world's largest aluminum producer, although none of its mines are in Canada. All these firms possess mineral reserves which have the potential to keep them in the forefront of world mineral production well into the 21st century. They are also the principal performers and funders of industry R&D in mining and minerals (see table 5.14, later in this chapter).

Vertical integration is of course very pronounced in the iron ore industry as well, where all Canadian producers are tied directly to steel producers in the United States and Canada.

Junior Mining

Firms engaged in junior mining are involved exclusively in exploration, holding or trading of promising mineral properties, or, in some cases, in mine development. Once their properties come into production, they cease, by definition, to be juniors. The distinction is based almost entirely on the presence or absence of income from mineral production. There were 225 mining companies in Canada in 1985; since the Canadian Mines Handbook lists well over 2,000 companies, it is clear that juniors outnumber producers by about ten to one. Juniors are also, as confirmed in tables 5.2 and 5.4, much smaller in terms of asset size.

Because juniors are small and in most cases have no income, they are as a rule unable to conduct any R&D and hesitant to try out unproven technology. However, Canadian exploration equipment companies have led the world in many areas of R&D and innovation, and contributed significantly to the excellent overall performance of Canada's junior companies.

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2. Vertical integration refers to the control by one company over separate units that are engaged in successive stages of production or distribution. The separate establishments may be divisions within a single company or may be separately incorporated companies in which a parent has a majority or minority interest. In the context of mineral production, the successive stages which may be integrated are: exploration, development, mining and milling, smelting, refining, further fabrication, and possibly marketing.

Contractors and Consulting Firms

Like junior mining firms, these companies are numerous, relatively small, and not owners of producing mines. They provide services to all aspects of the mineral production cycle: exploration; feasibility and design studies; mine development; operation or advice for mining, processing, smelting, and refining facilities; and studies in product markets and marketing. Their services may involve hands-on contract work such as exploration field programs, mine construction or operation, or construction of processing facilities; or, it may take the form of reports in areas such as geological potential, analysis of geological data, feasibility studies in mining or processing, operations and management, environmental and health and safety concerns, productivity, and market access or market potential.

Many consulting and contracting firms specialize in mining activities exclusively, or in one aspect of mining such as exploration or marketing, while others, particularly those in the construction end, deal with a wide range of sectors comprising resource and manufacturing industries.

These firms are an important source of new technology for the industry. Unfortunately, they are rarely if ever in a position to conduct R&D, and are severely limited in their ability to try out new but unproven technology because of the tight budgets and schedules under which they operate. They do, however, introduce and adapt proven technology from other countries and other sectors. In some cases they also undertake technology development and demonstration assignments for larger operating firms, equipment suppliers, or government agencies.

In an attempt to identify the research activities of this sector of the industry, CRS sent questionnaires to 241 companies identified from various sources, including the consulting engineers handbook and lists of exhibitors at meetings and advertisers in journals. The response rate was 25 percent, or 60 firms, of which 9 reported R&D in mining, processing, or metallurgy. The nine firms reporting R&D spent a total of about $200,000 on R&D in 1985, and the three firms that reported both R&D expenditures and revenues spent an average of only 0.3 percent of revenues on R&D in 1985. Spread over the entire the group of companies, the R&D intensity would be negligible. (Another 19 firms reported R&D in geosciences in 1985, of those, 15 firms that reported both R&D and revenues spent an average of 7.7 percent of revenues on R&D).

Equipment Suppliers

Canada does not have a strong domestic mining equipment sector. The mining industry purchases a wide variety of equipment, totalling about $2 billion in current dollars in 1987, as shown in table 5.7. These equipment purchases are made from a broad cross-section of both general and mining-specific equipment suppliers. Much of the machinery used in mining is of a general purpose nature, and is also employed in other industries such as construction. The Mineral Industry Purchasing Handbook lists over 1,000 Canadian suppliers of mining equipment; for most of these firms, mining equipment is a sideline, accounting for only a fraction of their total business.

Table 5.7 Mining Equipment Related Expenditures[a], 1971-87
(1981 $ million)

Year	Capital Expenditures (Equipment)	Maintenance Expenditures (Equipment)	Total Equipment Expenditure	Total in Current $ million
1971	824.3	830.5	1,654.9	693.4
1975	677.9	941.1	1,619.0	981.1
1980	909.0	1,178.3	2,087.3	1,884.8
1981	954.0	1,230.3	2,184.3	2,184.3
1982	902.0	1,281.4	2,183.5	2,377.8
1983	665.2	1,098.9	1,764.0	2,016.3
1984	793.7	1,054.4	1,848.3	2,188.4
1985	635.7	1,126.6	1,762.3	2,157.1
1986	473.7	1,076.7	1,550.4	1,950.4
1987	473.8	1,064.1	1,537.7	1,986.7

Source: Statistics Canada, 61-206.
[a] includes coal mining, excludes petroleum and gas.

In 1982 the federal Department of Industry Trade and Commerce (ITC) published A Profile of the Mining Machinery and Equipment Sector in Canada, which described the sector as comprising about 120 firms, largely in Ontario and Quebec, employing 6,000 people directly in the production of mining equipment. Annual shipments in 1982 were about $342 million in current dollars, of which about 60 percent was exported, mainly to the United States. Growth in the sector was described by ITC as about 12.2 percent between 1965 and 1985, slightly ahead of both the machinery industry as a whole and total manufacturing (both 11 percent). The sector was then dominated by about 12 large foreign-owned firms whose integrated operations were not restricted to mining equipment. The sector's technical capability was described as good in the ITC study, but based largely on imported technology.

The larger Canadian equipment manufacturers that are subsidiaries of foreign corporations include Joy Manufacturing, Atlas Copco, Ingersoll Rand, Caterpillar Tractor, and Jarvis Clarke (originally Canadian-owned and still the largest domestic manufacturer of underground mining equipment). Most of these firms import a substantial proportion of their goods for sale from foreign plants, mainly in the United States.

The foreign domination is reflected in the degree of import penetration in Canada by foreign mining equipment manufacturers. In their 1982 study, ITC reported that imports of mining machinery in 1980 captured 73 percent of the Canadian market share, up from 52 percent in 1965. This estimate of 27 percent Canadian sourced in 1982 appears high, when compared with Statistics Canada's figures on equipment expenditures shown in table 5.7. According to ITC, the 1982 annual Canadian shipments were $342 million, so the Canadian purchases, at 40 percent of Canadian production, were $136 million. This represents only about 15 percent of the capital expenditures shown in table 5.7 for 1982, and less than 6 percent of total expenditures for mining-related equipment in Canada.

Most of the Canadian-owned mining and mineral processing equipment manufacturers are small, with sales of less than $10 million annually. They face considerable disadvantages compared to larger firms in terms of scale economies, distribution facilities, and access to technology. More importantly, since mining firms tend to be conservative purchasers of equipment, these small firms are at an additional disadvantage because they are generally perceived to be less stable, and unable to match the service offered by the larger firms.

To offset this disadvantage, some Canadian equipment suppliers are also distributors of foreign equipment. For example, Blackwood Hodge Limited derives approximately 80 percent of its revenues from the distribution of imported equipment and the remainder from its own manufacturing. Other manufacturers have attempted to find niches in the marketplace which may not be of interest to larger firms, and in which they can enjoy a relative technological advantage. Jarvis Clarke was the most successful, using this approach to capture a major share of the underground mobile equipment market in Canada before its takeover and subsequent resale.

In summary, the mining equipment and machinery sector in Canada is very small, and does very little R&D, relative to the overall size of the mining industry in Canada. Statistics Canada R&D expenditure data are not available for the mining equipment sector per se, but are published for the combined category of construction and mining machinery and materials handling equipment industry as shown in table 5.8. To help put these figures into perspective, the construction industry total equipment

expenditures in the 1980s were close to $2 billion per year, about the same as the total for mining. In view of the high degree of import penetration in the mining equipment sector, it seems reasonable to assume that Canadian mining equipment manufacturers spent significantly less than half of the total on R&D shown in table 5.8. If, for example, the industry spent one-third of the R&D total, it would have amounted to about $4 million in 1986. A more accurate estimation would probably be below $2 million. Note that R&D is shown in table 5.8 as a percent of sales of R&D performers, not as a percent of sales in the sector.

Table 5.8 Construction and Mining Machinery R&D Expenditures, 1979-1986

	Units	1979	1981	1982	1983	1984	1985	1986
Current intramural R&D expenditures	1981 $ million	10	12	11	10	8	11	12
Total intramural R&D expenditures	1981 $ million	11	15	13	10	10	11	12
Sales of R&D performers	1981 $ million	646	894	781	406	618	808	734
Reporting company sources of funds	percent	8	12	11	10	9	12	13
Current intramural R&D expenditure/sales	percent	1.5	1.3	1.4	2.3	1.4	1.3	1.6
Total intramural R&D expenditure/sales	percent	1.7	1.7	1.6	2.3	1.6	1.4	1.6

Source: Statistics Canada, special compilation, June 1988.

CANADIAN MINERAL INDUSTRY R&D EXPENDITURES

R&D Intensity

In order to set the R&D activities of Canadian mineral producers in context, this section begins with some background information on R&D intensity levels in the industrial sector in general, in other countries and in Canada.

Table 5.9 indicates that industry in Canada is significantly behind that of the major industrialized countries of the OECD in terms of the proportion of industry revenues that are reinvested in R&D, and shows no evidence of catching up.

Table 5.9 International Comparison of Industrial R&D Intensity, Selected Years
(Industrial R&D Expenditures/Domestic Product of Industry)

	1975	1981	1983	1984
Sweden	1.2	1.5	1.7	2.0
Finland	1.5	2.0	2.4	1.5
W. Germany	1.4	1.7	1.8	1.9
USA	1.6	1.7	1.9	2.0
Japan	1.1	1.4	1.6	1.9
France	1.1	1.2	1.2	1.3
Canada	0.4	0.6	0.6	0.7

Source: Statistics Canada, 88-202; Finland, Central Statistical Office of Finland, Science and Technology 1987, (Helsinki: 1987).

Table 5.10 indicates that in Canada the mining and ferrous metals industries are well below the already-low all-industry average R&D intensity in Canada, and losing ground in terms of this measure as of 1986. Only nonferrous metals are above the all-industry average of 0.7, with 1.4 in 1985. This is largely due to the inclusion of Alcan in this category in the Statistics Canada data (see table 5.12 for Alcan's R&D figures). The changes in intensity for mineral R&D may in some instances tell us more about changes in prices and sales than about changes in R&D expenditures. The variations also are a function of the number of firms reporting, and the reliability of the responses to the Statistics Canada R&D survey.

Table 5.10 Comparison of R&D Intensity[a] in Selected Canadian Industries, Selected Years

	1979	1981	1983	1985	1986
Mining	0.6	0.8	0.8	0.9	0.7
Crude petroleum and natural gas	0.8	0.6	0.6	0.6	0.6
Rubber and plastic	0.8	1.2	0.8	0.7	0.8
Wood	0.1	0.2	0.5	0.8	0.6
Pulp and paper	0.3	0.4	0.4	0.3	0.3
Primary metals (ferrous)	0.3	0.3	0.4	0.3	0.4
Primary metals (nonferrous)	0.9	0.7	1.2	1.4	1.3
Aircraft and parts	13.0	12.6	17.3	15.9	13.9
Electronic parts and components	11.2	8.2	5.3	7.4	6.7
Services	0.7	0.9	1.0	1.2	1.2
All-industry total	0.8	1.0	1.2	1.3	1.4

Source: Statistics Canada, 88-202, 1985, June 1987, p.90.
[a] Current intramural R&D expenditures as percent of company sales.

Table 5.11 shows that R&D intensity in the metal mining industry has remained relatively constant, at about 0.8 percent. Nonmetal mining R&D has climbed significantly since 1979, both in real dollars and in intensity. Ferrous metals R&D expenditures have been consistently the lowest in terms of intensity, and have shown no growth since 1979.

Table 5.11 Mineral Industry Current R&D Expenditures as percent of Sales of R&D Performers, 1979 and 1981-1986

	1979	1981	1982	1983	1984	1985	1986
Metal mines	0.7	0.8	1.2	0.8	0.7	0.9	0.6
Nonmetal mines	0.2	0.8	1.2	1.2	1.0	1.1	1.7
Services	-	0.7	0.9	0.7	0.9	1.0	1.5
Primary metals ferrous	0.3	0.3	0.3	0.4	0.3	0.3	0.3
Primary metals nonferrous	0.9	0.7	0.9	1.2	1.3	1.3	1.3
Nonmetallic mineral products	0.4	0.4	0.4	0.4	0.6	0.5	0.5

Source: Statistics Canada special compilation.

The figures shown in table 5.11 are misleading since the Statistics Canada ratios use only the sales of R&D performers as the denominator of their intensity ratio. A ratio using value of production for the sector would give a better picture of R&D expenditures in the industry as a whole. For comparison with the OECD figures in table 5.9, sector GDP value should be used as the denominator.

Using the most recent data available, CRS calculated ratios for 1986 using value of production and GDP values for mining, and GDP values for primary metals. The results are shown in table 5.12. Only current

Table 5.12 CRS Measures of R&D Intensity in the Mining and Metals Sectors, 1986

	Current Intramural R&D Expenditures		Total Intramural R&D Expenditures	
	As % of Value of Production	As % of GDP Value of Sector	As % of Volume of Production	As % of GDP Value of Sector
Mining	0.29	0.37	0.32	0.41
Metals	na	1.50	na	1.64

Source: Derived from tables 2.2, 2.4 and 5.13.

expenditures are usually used for such ratios, since capital expenditures tend to be sporadic and less useful in identifying trends. Only in the case of nonferrous metals do any of these R&D intensity figures approach the Statistics Canada figures reported in table 5.10.

Statistics Canada Mineral Industry R&D Data

Table 5.13 is notable chiefly for the separate identification of Alcan's R&D expenditures in Canada, which permits us to look at the rest of nonferrous metals in isolation. The "other" nonferrous category shows a decline of an astounding 67 percent from 1980 to 1987.

Table 5.13 Summary of Mining and Metals Industry Intramural R&D Expenditures
(1981 $ million)

	1980	1981	1982	1983	1984	1985	1986[p]	1987[f]	1988[e]
Mining:									
Current	28	48	40	34	36	39	35	36	39
Capital	3	3	4	4	4	3	4	2	4
Total	31	51	44	38	40	42	39	38	43
Primary Metals Ferrous									
Current	22	22	20	18	21	19	19	20	20
Capital	1	2	1	1	1	2	2	5	3
Total	23	24	21	19	22	21	21	25	23
Primary Metals Nonferrous									
Alcan									
Current	32	38	42	42	44	50	41	52	na
Capital	8	7	7	3	5	3	3	8	na
Total	40	45	49	45	49	53	44	60	na
Other									
Current	36	32	28	26	28	21	23	15	na
Capital	19	10	2	1	3	1	3	3	na
Total	55	42	30	27	31	22	26	18	na
Total nonferrous									
Current	68	70	70	68	72	71	64	67	70
Capital	27	17	9	4	8	4	6	11	8
Total	95	86	79	72	80	75	70	78	78

Source: Statistics Canada, 88-202. Estimates derived from Statistics Canada forecasts by Centre for Resource Studies. Alcan data from internal documents; "other" derived by subtracting Alcan from Statistics Canada total.

Table 5.14 gives slightly more detail on R&D expenditures as reported by mining and primary metals firms to Statistics Canada. It has been supplemented by information received from Alcan, whose expenditures are included in the Statistics Canada nonferrous totals. It is interesting to note that current R&D expenditures for mining, like exploration expenditures, peaked immediately in response to the temporarily high metal prices of 1981 and fell off again immediately with declining prices. They had not recovered to 1981 levels by 1986.

Note that although both data series (tables 5.13 and 5.14) were prepared by Statistics Canada some of the figures do not match, due to differences in timing. Table 5.14 is based on actual survey data published in 1988.

Table 5.14 Mining and Metals Industry Total Intramural R&D Expenditures, 1979 and 1981-86
(1981 $ million)

	1979	1981	1982	1983	1984	1985	1986
Mining:							
Metallic	22	41	31	25	26	28	25
Nonmetallic	1	6	8	11	11	11	11
Services	-	3	3	3	3	3	2
Mining total	23	50	42	39	40	42	38
Metals:							
Ferrous	23	24	22	18	22	21	21
Nonferrous:							
Alcan	na	45	49	45	49	53	44
Other	na	42	30	27	31	23	26
Total	72	86	79	72	80	76	70
Nonmetallic mineral products	7	8	7	9	14	14	11

Sources: Statistics Canada special compilation, June 1988; except for Alcan, which is from Alcan internal documents; "other" is derived from Statistics Canada total minus Alcan figures.

Note: These figures differ from those presented elsewhere in the report. They are based on a special compilation rather than published data used in other tables.

Alcan's R&D expenditures are the figures reported by Alcan to Statistics Canada for inclusion in the primary metals nonferrous category; they represent over half of the primary metals nonferrous category in 1980; by 1986 Alcan's share rose to 63 percent. The "other" category consists of other Canadian smelting and refining operations, principally for base metals and nickel. As noted, real R&D expenditures in the "other" nonferrous sector fell by 67 percent over the period 1980 to 1987, (table 5.13), from $55 million to $18 million.

Complicating the R&D data in the nonferrous metals category is the fact that no distinction is made by Statistics Canada between research in extractive metallurgy and production processes, and research on new product development and properties of materials. In discussion with research managers, CRS has gathered the following impressions, which at least give some conception of trends and orders of magnitude. Nonferrous metals research managers point out that it is sometimes difficult and even meaningless to make distinctions between process and product research; the two aspects should be part of an integrated process. In general, the split of effort, insofar as it can be distinguished, seems to be about 70 to 80 percent in the process area and 20 to 30 percent in the nonferrous metals product area (excluding Alcan). The trend is shifting towards greater emphasis on product research. This trend holds true for Alcan as well, although Alcan is further advanced in the move towards products. Alcan reports that in 1982 its new product research accounted for 10 percent to 20 percent of total R&D effort. By 1987, the figure had risen to about 40 percent in new products, with 30 percent for fabrication and 30 percent for R&D related to raw materials and electrolytic processes.[3]

Environmental-driven R&D expenditures are also difficult to isolate, since they too are integrated, particularly into the process R&D activities. Indications are that they account for about 15 to 25 percent of the research effort of the larger base metal firms, and 25 percent for Alcan.

In ferrous metals, industry spokesmen again stress the integration of process and product R&D, but estimated a reverse relationship to that found in nonferrous metals. It appears that in ferrous R&D 30 to 40 percent of expenditures are devoted to process, and 60 to 70 percent to product development. Of the latter, about half is on physical metallurgy, and half on properties of materials.

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3. Alcan, internal documents.

Company-Specific R&D Expenditure Information

Table 5.15 lists the 9 largest mineral companies as indicated by the Financial Post's annual survey of Canadian corporations, and shows the R&D expenditures for those companies that publish this information. The tenth largest, QIT Fer Et Titane, is a wholly-owned subsidiary of BP America and does not publish an annual report.

The data provided in table 5.15 cannot be compared directly to that in tables 5.12 to 5.14, since most of the companies shown here report to Statistics Canada in both the mining and the primary metals categories. Alcan's data, which is reported to Statistics Canada for Canada only in the category of nonferrous primary metals, includes both Canadian and foreign R&D expenditures in table 5.15. Inco's R&D totals in table 5.15 include foreign expenditures as well.

Rio Algom does not classify any of its expenditures as R&D. However, it does spend about $1.5 million per year on process and product development, including its work on leaching of uranium ores and development of steel products.

In terms of R&D intensity, only Alcan and Inco report expenditures consistently higher than one percent of operating revenues. While Alcan's R&D expenditures and intensity were climbing until 1987, Inco's show a sharp drop in 1983, continuing to 1986. The drop reflects the 1981 closure of Inco's Sterling Forest facilities in the United States, where research on new products was conducted. Falconbridge's R&D cut after 1981 reflects the closure of its Metallurgical Laboratory north of Toronto.

Although R&D expenditures are not available for all companies and for all years, the total reported in table 5.15 for 1986 is $99 million (1981 dollars). This is close to the $95 million reported in table 5.13 for metal mines and primary nonferrous metals. It would appear therefore that the companies shown in table 5.15 account for most of the nonferrous mining and processing R&D in Canada.

In ferrous metals, the Canadian Steel Industry Research Association (CSIRA) estimates that its member companies conducted intramural R&D amounting to $18 to $20 million in 1987, concentrated mainly in four firms. The largest R&D effort by far is that of Stelco, at over $10 million. Dofasco is second, at $5-$6 million, followed by Algoma and Sidbec Dosco who contribute most of the remaining expenditures.[4]

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4. Frank Pearce, CSIRA, personal communication, September 1988.

Table 5.15 Company-Specific R&D Expenditure Information, 1980-1987 (1981 $ million)

	1980	1981	1982	1983	1984	1985	1986	1987
ALCAN (U.S. $)								
Sales & operating revenue	5,829	5,053	4,324	4,556	4,617	4,672	4,734	5,189
Net income (loss)	600	264	(53)	64	214	(147)	194	303
R&D expenses	na	na	51	52	56	63	61	73
R&D intensity (%)	na	na	1.2	1.2	1.2	1.3	1.3	1.4
Total assets	6,074	6,346	6,090	5,774	5,650	5,605	5,658	5,847
COMINCO								
Sales	1,598	1,417	1,134	1,203	1,335	1,191	1,056	997
Net earnings (loss)	189	70	(28)	(34)	20	(79)	(121)	(131)
R&D expenses	na	6	5	na	5	4	5	5
R&D intensity (%)	na	0.4	0.4	na	0.3	0.4	0.5	0.5
Total assets	1,509	1,686	1,595	1,455	1,375	1,243	1,150	1,235
DENISON								
Revenue	302	311	499	483	469	453	328	
Net earnings (loss)	81	62	44	81	54	(129)	36	
R&D expenses	na	na	na	na	na	na	na	
R&D intensity (%)	na	na	na	na	na	na	na	
Total assets	1,120	1,365	1,408	1,447	1,578	1,324	1,258	
FALCONBRIDGE								
Revenue	839	713	444	538	619	727	910	
Net earnings (loss)	83	1	(74)	(27)	24	32	(13)	
R&D expenses	8	11	6	3	3	4	4	
R&D intensity (%)	0.9	1.5	1.2	0.5	0.4	0.6	0.4	
Total assets	1,363	1,335	1,070	1,105	985	1,104	2,138	
INCO (U.S. $)								
Net sales	2,381	1,236	1,077	1,284	1,259	1,186	910	
Net earnings (loss)	257	(470)	(186)	(206)	(65)	42	0	
R&D expenses	38	37	33	25	19	18	17	
R&D intensity	1.6	3.0	3.1	2.0	1.5	1.5	1.9	
Total assets	5,228	3,856	3,189	2,785	2,627	2,519	2,366	

Table 5.15 Company-Specific R&D Expenditure Information, 1980-1987 (continued)
(1981 $ million)

	1980	1981	1982	1983	1984	1985	1986	1987
NORANDA								
Revenue	3,291	3,029	4,279	4,513	4,686	4,766	4,925	5,623
Net earnings (loss)	461	169	(73)	(22)	(4)	(208)	34	263
R&D expenses	8	8	na	8	8	8	10	na
R&D intensity (%)	0.2	0.3	na	0.2	0.2	0.2	0.2	na
Total assets	3,535	4,428	5,823	5,559	5,618	5,361	5,176	6,119
PLACER DEVELOPMENT								
Sales	313	291	234	225	258	345	347	
Net earnings (loss)	103	51	(12)	24	36	29	56	
R&D expenses	na	na	na	na	na	na	na	
R&D intensity (%)	na	na	na	na	na	na	na	
Total assets	784	829	805	755	1,064	811	950	
RIO ALGOM								
Revenue	939	918	698	682	965	1,002	1,079	1,170
Net earnings (loss)	85	66	17	45	63	72	56	71
R&D expenses	na	na	na	na	na	na	na	na
R&D intensity (%)	na	na	na	na	na	na	na	na
Total assets	1,175	1,241	1,245	1,389	1,434	1,498	1,617	1,589
SHERRITT								
Revenue	401	330	254	297	338	364	311	
Net earnings (loss)	28	(8)	(1)	4	(11)	(12)	(22)	
R&D expenses	2	2	1	2	na	na	2	
R&D intensity (%)	0.6	0.6	0.4	0.6	na	na	0.5	
Total assets	342	421	552	563	568	532	390	

Source: Company annual reports and Financial Post Business Information Services. Alcan and Inco R&D expenses include both Canadian and foreign R&D activities, and are shown in US dollars, as reported in their annual reports.

INDUSTRY R&D ORGANIZATIONS

Introduction

There are no industry facilities in Canada for conducting joint or collaborative mining or mineral-related R&D. There are, however, a growing number of organizations established to coordinate R&D conducted in-house or in non-industry facilities. These include the following:

Cooperative research (organizations for R&D performed and funded by member companies in-house, or on contract on behalf of individual member companies):

MIROC, focusing on health and safety;
HDRK, focusing in continuous mining in hard rock;

Research coordination and promotion:

MITEC, national coordination of mining and metallurgical R&D;
MRD, focusing on ground control in Ontario;
NACMA, the National Committee on Mining Automation, an informal advisory group;
CSIRA, focusing on steel-making technology.

Cooperation in market promotion and product development R&D

- Nickel Development Institute (NiDI) - international, industry funded, R&D contracted out;
- Asbestos Institute - federal and Quebec government and industry funded;
- Potash and Phosphate Institute - government and industry funded.

Five of these organizations are described briefly below. The expenditure figures provided here have already been given in the earlier tables in this chapter and do not represent additional funding.

Cooperative mineral R&D is in the very early stages in Canada, and involves very little actual funding support up to the present time. Most of the influence of these organizations involves identification of targets for existing R&D funding and facilities. However, there are indications that these organizations will be successful in improving communication, in increasing the overall level of funding support and in establishing new centres of excellence, for example around the university chairs that are being established in mineral-related departments.

Cooperative Research Organizations

Mining Industry Research Organization (MIROC)

Miroc was established in 1970 by seven Canadian mining companies to conduct cooperative R&D. Its activities are relatively small in scale, and generally relate to health and safety matters. Among the projects carried out by its member companies have been:

- improvement of miners' personal working gear with respect to respiratory protection and hearing, and improvement of lighting equipment including development of an air-flow helmet, a halogen cap lamp, a miners' worksuit, and a protective workbook;
- development of a monitoring system for mine ventilation;
- development of a new concept for underground radio communication;
- development of an underground system for air-powered space lighting.

HDRK Mining Research Limited

HDRK is a joint venture established in 1984 by Inco, Noranda, Kidd Creek, and Falconbridge to conduct R&D on strategic innovations of mutual interest. The annual budget for HDRK was originally set at $1 million and it is expected to reach about $2.8 million in 1988. Its objective is to generate evolutionary (rather than revolutionary) improvements in hardrock mining productivity through the development of a continuous-type mining system.

HDRK has no research facilities of its own, but contracts work out to other technical organizations, including, but not limited to, the joint venture partners. It is established as an "agent corporation", rather than as an R&D company. The member companies put no funds beyond administrative support into HDRK. Instead, for each project, one of the three member companies is identified as the manager and bears all the up-front costs, in consultation with HDRK's administrator. Each quarter, the other two companies reimburse the project manager for their share of expenditures. These expenditures are reported to Statistics Canada as "intramural R&D, own source." Although some of its projects are still in the planning stage, HDRK's research interests include:

- development of technologies, techniques and equipment for cutting of hardrock with high pressure water jets and associated equipment and materials;
- improved productivity in raise boring;

- for the long term, various studies of continuous mining methods, including the use of ore sorters in conjunction with the continuous breaking of rock.

Research Coordination and Promotion

The Canadian Steel Industry Research Association (CSIRA)

CSIRA is one of the most successful mineral R&D coordination organizations, in terms of impact on focus and cooperation in its area of interest, the technology of steel-making. It was established in 1978 to coordinate the research efforts of the steel industry and of government and university research activities related to steel. Membership is limited to Canadian-based steel companies with both melting and rolling facilities. There are 11 industry member companies: Algoma Steel Corporation, Atlas Specialty and Stainless Steel Divisions, Courtice Steel, Dofasco, Ipsco, Ivaco, Lake Ontario Steel, Manitoba Rolling Mills, Sidbec Dosco, Slater Industries and Stelco. In addition, CANMET, DRIE, NRC and McGill have ex-officio representatives. Among the major accomplishments of CSIRA have been the endorsement of a CSIRA/NSERC chair in steel processing at McGill University and the organization of a national steel strip casting research and development project.

The association does not have its own research program. It encourages technical interchange and the direct sponsorship of research by its member companies, either in-house or in universities, and promotes cooperative efforts in targeted areas of interest. It also communicates the needs of the industry to universities, colleges and technical schools.

Mining Industry Technology Council (MITEC)

Funded by the Mining Association of Canada (MAC) in 1987, MITEC's mission is to "improve the competitive position of the Canadian mining industry by optimizing the development and use of advance technology and methods". During the present start-up stage, MITEC's budget is about $150,000 per year. There are plans to establish an initial project on a mine communication system, at an estimated $200,000, ahead of the normal process. All projects will be contracted out by MITEC to industry, universities, government facilities, research contracters and consultants.

Ontario Mining Association's Mining Research Directorate (MRD)

MRD was established by the Ontario Mining Association (OMA) in 1987. Its Board of Directors includes representatives of the OMA, the federal and Ontario governments, organized mine labour, and senior staff from Denison, Falconbridge, Inco, and Noranda.

MRD's function is to promote and coordinate research in rock mechanics and ground control. Expenditures are expected to be about $200,000 per year, initially, reaching $2 million per year in about 5 years, and matching funds are being sought from the Ontario government's Technology Fund.

CONCLUSION

Summary table 5.16 shows a peak in real R&D expenditures for metal mining in 1981, a peak which was the result of current expenditures and not a surge in capital R&D outlays. Metal mining then declined in 1986, while other mining showed a rapid increase. Table 5.13, which disaggregated nonferrous metals, indicated that primary metals nonferrous excluding Alcan showed the most severe decline in real R&D expenditures while Alcan held steady. Ferrous metal fell to 1983, and recovered slightly by 1986.

In terms of R&D intensity, the measures vary but it appears that only Alcan and Inco among the major R&D performers exceed or even approach an R&D intensity of 1 percent of sales. Excluding these two firms, it appears that all sectors of the mineral industry have an R&D intensity well below 0.5, and that the vast majority of firms do no R&D at all.

This statistical evidence suggests that R&D across the mineral industry in Canada, in mining and in smelting and refining, is seriously underfunded and getting worse. The estimates for 1988 shown in table 5.13 show an anticipated increase of 13 percent from 1987 in the mining sector. However, forecasts have been overestimated by as much as 20 percent in recent years (eg. 1987 forecast $46 million, vs $38 million actual) so it is not yet clear whether a reversal of the decline has actually begun. In primary metals, the decline in real R&D funding appears to be continuing.

Table 5.16 Summary of Mineral Industry R&D, 1979-1986

	Units	1979	1981	1982	1983	1984	1985	1986
Metal Mining								
R&D expenditures	1981 $ m.	22	41	31	25	26	28	25
R&D/performers' sales[a]	%	0.7	0.8	1.2	0.8	0.7	0.8	0.6
Sector value added	1981 $ m.	6,363	4,704	3,211	3,263	3,937	3,656	na
R&D/value added[b]	%	0.3	0.9	1.0	0.8	0.7	0.8	na
Other mining (industrial and coal)								
R&D expenditures	1981 $ m.	1	6	8	11	11	11	11
R&D/performers' sales[a]	%	0.2	0.8	1.2	1.2	1.0	1.1	1.7
Sector value added	1981 $ m.	2,632	2,463	1,864	1,831	2,430	2,118	na
R&D/value added[b]	%	0.0	0.2	0.4	0.6	0.4	0.5	na
Primary metals - ferrous								
R&D expenditures	1981 $ m.	23	24	22	18	22	21	21
R&D/performers' sales[a]	%	0.3	0.3	0.4	0.3	0.3	0.3	0.3
Sector value added	1981 $ m.	3,680	3,395	2,525	2,628	3,190	3,240	na
R&D/value added[b]	%	0.6	0.7	0.9	0.7	0.7	0.6	na
Primary metals - nonferrous								
R&D expenditures	1981 $ m.	72	86	79	72	80	76	70
R&D/performers' sales[a]	%	0.9	0.7	0.9	1.2	1.3	1.4	1.3
Sector value added	1981 $ m.	2,426	2,441	1,886	2,268	2,621	2,432	na
R&D/value added[b]	%	3.0	3.5	4.2	3.2	3.0	3.1	na

Source: Statistics Canada special compilation, June 1988 (R&D and sales).
The Canadian Mineral Industry, Monthly Report, October 1987, p. 6. (value added).

[a] This ratio was derived by Statistics Canada using current R&D and sales of performers only.

[b] This ratio is derived using current R&D and value added in the entire sector as shown in this table.

6. EDUCATION TRENDS

Introduction

This chapter looks at three principal indicators of education trends in mining and metallurgy, and in selected other disciplines for comparative purposes. The characteristics of education considered are:

- funding sources and levels
- number and rank of faculty
- undergraduate and graduate student enrollment and degrees granted.

Education funding trends will be considered in the study only at the aggregate level for all Canada, with some reference to provincial differences.

Information on faculty and enrollment will be presented in two levels of detail. First, a comparative section will give Statistics Canada data on overall trends by major discipline categories. Second, a more detailed section on mining and metallurgy alone will draw on information collected by the Education Committee of the Canadian Institute of Mining and Metallurgy (CIM) and responses to the CRS survey of university departments.

EDUCATION TRENDS: CANADIAN COMPARISON

Education Funding

Operating funds for education purposes in Canadian universities comes principally (almost 80 percent) from the provincial governments as shown in tables 6.1 and 6.2. Total university funding includes, in addition to operating income, sponsored research and other sources including gifts and capital grants (see tables 6.3 and 6.4). The research component of university funding will be considered in more detail in chapter 7. Over the period 1980/81 to 1985/86, operating funds increased by 8.7 percent in real terms, but fell by 10 percent on a per-student basis (table 6.5).

Unfortunately, it is impossible to produce figures for university funding support for education by department or by academic discipline, since each university receives its provincial operating grant as a lump sum, based on a formula related to enrollment. This amount is then allocated within each university at the discretion of the administration, according to each university's priorities and commitments.

Table 6.6 shows university operating expenditures by province and their contribution to provincial GDP.

Table 6.1 University General Operating Income by Source of Funds, 1980/81 - 1985/86
(1981 $ million)

Source	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86
Federal government	44	57	73	79	68	67
Provincial government	2,774	2,785	2,859	2,870	2,856	2,920
Fees	444	469	521	553	577	591
Other sources[a]	126	136	137	116	117	105
Total	3,388	3,447	3,590	3,618	3,618	3,683

Source: Statistics Canada, 81-260.
[a] Includes gifts and investment income.

Table 6.2 University General Operating Income by Source of Funds, 1980/81 - 1985/65
(percent contribution by source)

Source	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86
Federal government	1.3	1.7	2.0	2.2	1.9	1.8
Provincial government	81.9	80.8	79.6	79.3	78.9	79.3
Fees	13.1	13.6	14.5	15.3	16.0	16.1
Other sources[a]	3.7	4.0	3.8	3.2	3.2	2.8
Total	100.0	100.0	100.0	100.0	100.0	100.0

Source: Table 6.1.
a includes gifts and investment income.

Table 6.3 Total University Income, by Source of Funds, 1980/81 - 1985/86 (1981 $ million)

Source	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86
Federal government	380	432	457	508	539	543
Provincial government	3,079	3,114	3,253	3,295	3,215	3,296
Fees	444	469	521	553	582	595
Other sources[a]	872	886	899	879	942	964
Total	4,775	4,901	5,130	5,236	5,278	5,398

Source: Statistics Canada, 81-260.
a Includes gifts and investment income.

Table 6.4 Total University Income by Source of Funds 1980/81 - 1985/86 (percent contribution by source)

	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86
Federal government	8.0	8.8	8.9	9.7	10.2	10.1
Provincial government	64.5	63.5	63.4	62.9	60.9	61.1
Fees	9.3	9.6	10.2	10.6	11.0	11.0
Other sources[a]	18.3	18.1	17.5	16.8	17.9	17.9
Total	100.0	100.0	100.0	100.0	100.0	100.0

Source: Table 6.3.
[a] includes gifts and investment income.

Table 6.5 Indicators of University Operating Income, 1980/81 - 1985/86

Indicator	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86
As percent of GDP	0.99	0.97	1.04	1.02	0.97	0.95
Per capita (1981 $)	142	144	147	145	144	145
Per student[a] (1981 $)	7,483	7,274	7,145	6,825	6,694	6,712
Per faculty[b] (1981 $)	101,721	102,589	105,358	105,545	104,385	104,708

Source: Statistics Canada, 81-241 and 81-260.
a full time equivalent (FTE).
[b] includes adjunct.

Table 6.6 University General Operating Expenditures, by Province, 1980/81 and 1985/86
(1981 $ million, % of total, % change)

Province	1980/81		1985/86		% Change 1980/81-1985/86
	$	%	$	%	
Newfoundland	74.3	2.2	80.2	2.1	7.9
PEI	10.0	0.3	12.6	0.3	26.0
New Brunswick	92.4	2.7	103.5	2.8	12.0
Nova Scotia	148.8	4.4	175.0	4.7	17.6
Quebec	969.3	28.5	972.9	26.0	0.3
Ontario	1,214.3	35.7	1,414.1	37.8	16.5
Manitoba	137.3	4.0	162.2	4.3	18.1
Saskatchewan	131.6	3.9	146.3	3.9	11.2
Alberta	301.9	8.9	362.5	9.7	20.1
British Columbia	325.4	9.6	312.1	8.3	-4.1
Canada	3,405.3	100.0	3741.4	100.0	9.9

Source: Statistics Canada, 81-260.

University Teaching Staff

Tables 6.7 and 6.8 show the total number of university teaching staff by academic rank for all of Canada, and how that distribution has changed over the 1980s. Table 6.9 shows the distribution of teaching staff (total) by major field of study. The health sciences showed the greatest growth in number of teaching positions, followed by engineering and applied sciences.

Table 6.7 Number of University Teaching Staff, by Rank, Canada, 1980/81 - 1985/86

Rank	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86
Full professor	9,804	10,310	11,054	11,582	11,959	12,382
Associate	12,550	12,707	12,900	12,925	12,985	12,940
Assistant	7,367	7,136	6,890	6,934	6,946	7,066
Others	3,578	3,447	3,235	2,840	2,776	2,783
Total	33,299	33,600	34,079	34,281	34,666	35,171

Source: Statistics Canada, 81-241.

Table 6.8 Number of University Teaching Staff, by Rank, Canada, 1980/81 - 1985/86
(Percent of Total)

Rank	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86
Full professor	29.4	30.7	32.4	33.8	34.5	35.2
Associate	37.7	37.8	37.9	37.7	37.5	36.8
Assistant	22.1	21.2	20.2	20.2	20.0	20.1
Others	10.8	10.3	9.5	8.3	8.0	7.9
Total	100.0	100.0	100.0	100.0	100.0	100.0

Source: table 6.7.

Table 6.9 Number of University Teaching Staff by Field of Study, Selected Years

	1980/81		1985/86		Average Annual % Change 1980/81 - 1985/86
	Number	% of Total	Number	% of Total	
Education	3,148	9.6	3,098	8.9	-0.3
Fine & applied arts	1,382	4.2	1,487	4.3	1.5
Humanities	5,704	17.4	5,915	17.0	0.7
Social sciences	8,349	25.4	8,819	25.3	1.1
Agriculture & biological sciences	2,377	7.2	2,382	6.8	0.0
Engineering & applied sciences	2,479	7.5	2,723	7.8	2.0
Health professions	5,103	15.5	5,748	16.5	2.5
Mathematics & physical sciences	4,330	13.1	4,709	13.5	1.8
Total reported	32,870	100.0	34,881	100.0	1.1
Not reported	429		290		
Total	33,299		35,171		1.2

Source: Statistics Canada 81-241.

Enrollment

Tables 6.10 and 6.11 illustrate enrollment changes, in response to shifting interests, priorities and student perceptions of employment opportunities. The resource sector fields have seen a decline in enrollment, as have some branches of engineering, while the humanities, social sciences and biology have grown significantly.

Table 6.10 Undergraduate Enrollment by Field of Study, Selected Years

	1980/81		1985/86		Average Annual $ Change 1980/81 - 1985/86
	Number	% of Total	Number	% of Total	
Education	36,071	13.0	40,760	11.7	2.6
Fine & applied arts	12,302	4.5	14,236	4.1	3.1
Humanities	24,132	8.7	33,375	9.6	7.7
Social sciences	93,943	34.0	123,465	35.4	6.3
Agriculture, biological	20,188	7.3	27,059	7.8	6.8
Engineering, applied science	38,441	13.9	41,360	11.9	1.5
Health professions	22,237	8.0	24,757	7.1	2.3
Mathematics & physical sciences	19,238	7.0	29,264	8.4	10.4
Other[a]	9,856	3.6	14,066	4.0	8.5
Total	276,408	100.0	348,342	100.0	5.2

Source: Statistics Canada, 81-204.
[a] other excluding arts/sciences general.

The distribution of all faculty in mining engineering and in metallurgical and materials science over the 1980-85 period are shown in tables 6.13 and 6.14. Total mining engineering faculty increased in this period, but there was no increase in metallurgical and material science teaching staff. The proportion of full professors has grown in the latter groups, suggesting both aging of the faculty and higher salary costs.

Table 6.11 Full Time Undergraduate Enrollment in Selected Disciplines, 1980/81 and 1985/86

Discipline	1980/81	1985/86	% Change 1980/81-1985/86
Geology[a]	2,341	2,435	0.8
Geography	4,396	5,083	3.1
Physics	1,756	2,890	12.9
Chemistry	2,659	3,937	9.6
Biology[b]	10,801	16,007	9.6
Agriculture[c]	5,750	5,252	-1.7
Forestry	2,107	1,689	-4.0
Engineering:	33,653	37,071	2.0
(Chemical)	(3,400)	(3,026)	-2.2
(Civil)	(4,676)	(4,224)	-1.9
(Electrical)	(6,324)	(8,421)	6.6
(Mechanical)	(5,368)	(7,125)	6.5
(Other)	(3,885)	(14,275)	0.6

Source: Statistics Canada 81-204.
a includes geophysics.
b includes biochemistry, botany and zoology.
c includes veterinary medicine.

MINING AND METALLURGY EDUCATION TRENDS

University Teaching Staff

There are 4 departments of mining or minerals engineering in Canadian universities, 4 departments that combine mining and metallurgy and 8 departments of metallurgy and/or materials science, as shown in table 6.12. The largest mineral faculty is at Ecole Polytechnique, with a total of 31, followed by Toronto with 21. In addition, a number of universities teach mining-related courses in civil engineering departments, and metallurgy and materials-related courses in chemical engineering, chemistry, and physics departments.

The distribution of all faculty in mining engineering and in metallurgical and materials science over the 1980-1985 period are shown in tables 6.13 and 6.14. Total mining engineering faculty have increased in this period, but there has been no increase in metallurgy and material science teaching staff. The proportion of full professors has grown in the latter group, suggesting both aging of the faculty and higher salary costs.

Table 6.12 Profile of Mining, Metallurgy and Materials Departments in Canadian Universities

University	Dept. or Program	Number of Faculty				
		Full Professor(FTE)	Associate Professor	Assistant Professor	Other	Total
Alberta 1987/88	Mining, metallurgical and petroleum engineering	13	3	0	0	16
British Columbia 1987/88	Metals and materials engin.	12	1	5	2	20
	Mining and mineral processing engineering	4	1	2	5	12
Laval 1987/88	Mining and metallurgy	7	5	3	0	15
Laurentian 1987/88	Extractive metallurgical engineering	2	1	2	0	5
	Mining engineering	2	3	1	0	6
McGill 1986/87	Mining and metallurgical engineering	6	4	8	0	18
McMaster 1987/88	Materials science and engineering	12	4	1	0	17
Polytechnique 1987/88	Metallurgical engineering	10	0	2	2	14
	Mineral engineering	8	4	3	2	17
Nova Scotia 1987/88	Metallurgical and mining engineering	2	8	0	3	13
Queen's 1987/88	Metallurgical engineering	2	3	2	1	8
	Mining engineering	2	4	1	0	7
Toronto 1987/88	Metallurgical engineering and materials science	11	3	3	4	21
Windsor 1986/87	Engineering materials	4	0	0	0	4
Western 1986/87	Materials engineering	2	2	2	2	8

Source: CRS survey of universities.

Table 6.13 University Faculty in Mining Engineering by Rank, 1980-85 (number and percent)

Rank	1980	1981	1982	1983	1984	1985	1985 % of Total
Full professor	20	22	27	29	27	26	44
Associate professor	18	16	13	16	16	18	30
Assistant professor	7	5	8	9	11	11	19
Othera	3	1	2	3	3	4	8
Total	48	44	50	57	57	59	100

Source: Statistics Canada, special compilation.
a includes "lecturers" and others undefined.

Table 6.14 University Faculty in Metallurgical and Materials Science, by Rank, 1980-85

Rank	1980	1981	1982	1983	1984	1985	1985 % of Total
Full professor	42	41	45	46	47	47	63
Associate professor	23	24	13	12	9	11	15
Assistant professor	8	9	9	10	12	16	21
Othera	3	2	2	2	2	1	1
Total	76	76	69	70	70	75	100

Source: Statistics Canada, special compilation.
aincludes "lecturers", "next rank" and others undefined.

Degrees Granted in Mining Related Disciplines

Tables 6.15 to 6.17 show trends in the number of degrees granted in disciplines related to mining, plus geology (arts and science). At both the Bachelors and Masters levels there is an increase in metallurgical engineering and a decline in growth in mining engineering. This is especially noticeable in Bachelor programs, where the number of graduates in mining engineering fell between 1980 and 1987. At the Masters level the number of graduates rose, but at a much slower rate than in metallurgical engineering. Petroleum engineering has been an increasingly popular undergraduate discipline, and the number of doctorates took a sharp jump in 1987.

Table 6.18 presents data on the number of mining technology degrees granted. The number of such degrees peaked in 1982-83, but by 1987 had fallen back to the pre-1980 level. All technology courses followed this trend of peak and decline.

Table 6.15 Undergraduate Degrees Granted in Mineral-Related Disciplines, 1980-87

	1980	1981	1982	1983	1984	1986	1987f
Geology (arts and science)	449	631	676	727	798a	na	na
Geology (engineering)	123	137	170	234	na	na	na
Geophysics (engineering)	9	8	31	37	na	na	na
Mining engineering	102	97	123	117	116	94	85
Metallurgical engineering	77	111	112	118	133	117	138
Metallurgy (arts & science)	6	23	13	18	27	13	7
Mineral dressing	21	na	na	na	na	na	na
Mineral processing (engin.)	na	27	16	19	21	13	23
Petroleum engineering	12	22	37	30	32	39	57

Source: CIM Bulletin, Education Survey, various years.
a Geology (arts & science and engineering).

Table 6.16 Masters Degrees Granted in Mineral-Related Disciplines, 1980-87

	1980	1981	1982	1983	1984	1986	1987[f]
Geology (arts and science)	121	161	149	149	227[a]	na	na
Geology (engineering)	6	8	16	4	na	na	na
Geophysics (engineering)	2	2	0	8	na	na	na
Mining engineering	16	17	15	24	34	16	46
Metallurgical engineering	23	44	41	50	51	78	97
Metallurgy (arts & science)	na	1	2	2	2	na	na
Mineral dressing	6	na	na	na	na	na	na
Mineral processing (engin.)	na	6	1	7	6	10	13
Petroleum engineering	6	4	1	2	3	4	7
Post graduate diplomas	1	6	40	32	26	9	14

Source: CIM Bulletin, Education Survey, various years.
a Geology (arts & science and engineering).

Table 6.17 PhDs Granted in Mineral-Related Disciplines, 1980-87

	1980	1981	1982	1983	1984	1986	1987[f]
Geology (arts and science)	36	50	62	46	72[a]	na	na
Geology (engineering)	2	0	0	1	na	na	na
Geophysics (engineering)	0	0	1	3	na	na	na
Mining engineering	2	1	2	3	3	2	7
Metallurgical engineering	15	23	11	15	17	26	46
Metallurgy (arts & science)	na	0	0	0	0	na	na
Mineral dressing	1	na	na	na	na	na	na
Mineral processing (engin.)	na	3	0	1	2	1	4
Petroleum engineering	0	0	0	0	0	1	12

Source: CIM Bulletin, Education Survey, various years.
a Geology (arts and science and engineering).

Table 6.18 Degrees Granted in Mining Technology, Selected Years

Disciplines	1976	1980	1981	1982	1983	1984	1986	1987f
Mineral	0	13	44	35	65	na	na	na
Mining	90	72	100	141	153	136	77	45
Metallurgy	72	95	88	165	151	147	123	93
Min. dressing	8	25	8	13	14	na	na	na
Geology	58	89	64	115	115	117	44	39
Geotechnical	na	8	13	45	48	na	na	na
Petroleum	58	153	157	210	174	153	174	180
Hydrocarbons	na	28	28	na	na	na	na	na
Other	18	17	15	70	75	163	29	63
Total	304	500	517	794	795	716	447	420

Source: CIM Bulletin, Education Survey, various years.

Tables 6.19 to 6.22 show undergraduate and graduate degrees granted, by university. The largest mining engineering department in terms of both undergraduate and graduate enrollment, has been Queen's, although 1987 saw a major drop in undergraduate degrees granted. As noted previously, undergraduate enrollment in mining peaked in the early 1980s and has fallen off since then. Graduate degrees granted have shown wide swings.

In metallurgy and metallurgical engineering no one university stands out as the major educator of students. As indicated in tables 6.21 and 6.22, there are more universities providing degrees in this area than there were in the mid-1970s. The total number of undergraduate degrees granted in metallurgy and metallurgical engineering has remained unchanged between 1981 and 1987, although the distribution by university has changed. In contrast, graduate degrees in the field have risen fairly steadily.

Table 6.19 Undergraduate Degrees in Mining Departments, Selected Years

	1976	1980[a]	1981[b]	1982[b]	1983[b]	1984[b]	1986[b]	1987[b]
Alberta	3	12	15	13	14	13	11	17
UBC	8	3	5	6	9	15	6	21
Polytechnique de Montreal	6	4	4	6	8	5	9	17
Laval	10	12	21	23	26	30	17	12
McGill	8	20	8	12	5	8	10	11
Nova Scotia	na	21	18	30	13	14	8	4
Queen's	30	30	30	36	45	36	29	13
Laurentian	0	14	12	11	12	12	13	10
Toronto	na	7	11	2	4	4	2	7
Total	na	123	124	139	136	137	105	105

Source: CIM Bulletin, Education Survey, various years.
[a] includes mining engineering and mineral dressing engineering.
[b] includes mining engineering and mineral processing.

Table 6.20 Graduate Degrees in Mining Departments, Selected Years

	1976	1980[a]	1981[b]	1982[b]	1983[b]	1984[b]	1986[b]	1987[b]
Alberta	1	3	4	2	1	3	0	3
UBC	3	2	1	1	2	6	5	9
Polytechnique de Montreal	9	6	5	1	1	3	1	3
Laval	6	3	4	1	7	5	9	7
McGill	4	3	2	5	7	3	5	6
Nova Scotia	na	0	1	1	0	1	0	6
Queen's	8	8	8	7	17	24	8	21
Laurentian	0	0	0	0	0	0	0	0
Toronto	na	na	2	0	0	0	1	0
Total	na	na	27	17	35	45	28	55

Source: CIM Bulletin, Education Survey, various years.
[a] includes mining engineering and mineral dressing engineering.
[b] includes mining engineering and mineral processing.

Table 6.21 Undergraduate Degrees Granted in Metallurgy and Metallurgical Engineering, Selected Years

	1976	1980	1981	1982	1983	1984	1986	1987
Alberta	5	2	8	6	9	5	6	9
UBC	na	5	12	9	6	17	20	23
Polytechnique de Montreal	12	na	21	14	8	13	12	19
Laval	7	11	12	12	17	24	13	16
McGill	18	14	10	13	10	7	13	10
McMaster	8	9	16	11	15	19	13	21
Nova Scotia	na	1	4	12	16	8	8	8
Queen's	8	14	13	15	18	19	7	6
Toronto	na	22	24	21	23	22	16	14
Western	na	na	12	9	8	17	6	7
Windsor	na	5	2	3	6	9	3	2
Total	na	na	134	125	136	160	117	135

Source: CIM Survey.

Table 6.22 Graduate Degrees Granted in Metallurgy and Metallurgical Engineering, Selected Years

	1976	1980	1981	1982	1983	1984	1986	1987
Alberta	3	0	5	0	3	4	3	3
UBC	na	4	5	9	10	11	15	14
Polytechnique de Montreal	5	na	23	6	5	9	4	11
Laval	11	7	3	3	6	6	14	14
McGill	3	7	6	11	8	6	15	17
McMaster	12	7	8	3	7	4	8	7
Nova Scotia	na	0	1	1	10	8	7	7
Queen's	1	2	4	3	3	5	6	4
Toronto	na	9	9	13	13	12	12	15
Western	na	na	1	2	2	2	5	3
Windsor	na	2	3	3	0	3	5	2
Total	na	na	68	54	67	70	94	97

Source: CIM Survey.

CONCLUSION

In terms of overall operating funds, Canadian universities seem to have done fairly well in the 1980/81 to 1985/86 period, with a real increase of close to 9 percent. However, enrollment increases have outstripped funding increases so that operating resources per student have fallen. Although there are less operating funds per student there has also been a rise in operating funds per faculty, indicating that the number of faculty has not increased to the same extent as has the number of students.

Trends in education in mining and metallurgy indicate a fairly strong and increasing interest in metallurgy as compared to mining. Degrees granted in metallurgy have increased at all levels but especially at the graudate level, and this bodes well for future innovative ability and effort in this area. In contrast, the number of undergraduate degrees in mining has fallen and while graduate degrees granted have risen, the total number is substantially less than the number of graduate degrees in metallurgy. To put these trends in context it must be remembered that mining has always been a more important sector than metals in the Canadian economy in terms of GDP (although not in terms of exports) and will continue to be more important for some time to come. It is also true, however, that the metals industry is growing faster than is the mining industry. It should also be noted that the metallurgy education figures given here do not distinguish between extractive metallurgy, which is directly related to production of basic metals, and physical metallurgy, which is more closely allied to downstream fabricating and new product development.

It is surprising to note that despite the apparent greater interest in metallurgy, it is in mining engineering departments that increases in faculty have occurred. In metallurgical engineering the number of faculty has not grown.

7. R&D IN SELECTED SCIENTIFIC DISCIPLINES

The comparison of mining and metallurgy R&D funding support with that of support for other fields of natural science and engineering will look at NSERC funding for university R&D for all disciplines. The second part of the chapter concentrates on mineral R&D in universities, with information from chapter 3 on NSERC support, supplemented by information collected by CRS from mining and metallurgy departments. Graduate student enrollment and degrees granted are also shown, in order to give a profile of trends in graduate student research.

DISCIPLINE COMPARISONS

University R&D Funding

University research funding represented about 13 percent of total university expenditures in 1985/86 and increased by about 40 percent in real terms since 1980. Almost all university research in Canada is sponsored research, supported by specific grants for specific purposes. The grants are provided by the federal government (about 60 percent), provincial governments (about 20 percent), and the remainder from donations and nongovernment grants and contracts. Table 7.1 indicates that over half of the sponsored research funding goes for salaries, and

Table 7.1 University Sponsored Research Funding, 1980/81 - 1985/86

	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86
SRI Total[a] (1981 $ million)	519.6	569.1	610.7	645.4	701.2	722.6
SRI as % of total university funding	11.0	11.8	12.0	12.4	13.3	13.3
Provincial grants as % of total SRI	17.7	17.7	19.7	18.6	18.4	18.9
Federal grants as % of total SRI	58.6	58.3	58.8	59.6	60.3	58.7
Salaries as % of total SRI	55.6	54.2	56.3	56.9	56.2	57.2

Source: derived from Statistics Canada, 81-260
a SRI = Sponsored research income

that this proportion is increasing. This suggests a continuing decline in the proportion of R&D funding available for increasingly costly research equipment and for its operation and maintenance.

Although the Statistics Canada data do not provide a discipline break-down of total university R&D support, a fair approximation is available through examination of federal support, the major funding source. Within the federal government, the major funding source for R&D in natural sciences and engineering is NSERC. NSERC support from committee grants is summarized by major discipline category in table 7.2. Committee grants represented about 57 percent of total NSERC funding in 1987/88, as shown in table 3.15, where they correspond to the category "research base". This proportion has shrunk from 68 percent in 1980/81, with a corresponding increase in support for targeted and scholarship funds.

Table 7.3 shows that major growth areas were mathematics and computing, engineering as a whole, physics and space, and psychology, all of which increased more rapidly than total research base support. The largest 2 categories were biology, with a rate of increase about the same as the overall rate, and engineering. Earth sciences, with only 7 or 8 percent of the total, grew much more slowly than the overall rate, and chemistry showed almost no growth. It is interesting to note that interdisciplinary R&D, although it receives a great deal of verbal support, is an almost negligible category in the NSERC classification system, receiving less than one percent of research base funding and showing no signs of increasing that proportion.

Mining and metallurgy combined, with figures taken from tables 3.18 and 3.19, showed strong growth which is almost entirely due to metallurgy, since the mining grants are negligible.

Table 7.4 shows distribution of NSERC strategic grants in 1980 and 1986. Strategic grants are short term awards aimed at fostering specific research projects which are intended to produce socio-economic benefits through transfer of results to the user sector. Unfortunately, the fixed term of the grants is usually unrealistic for solving serious technological problems. Although these grants represent only about 20 percent of the total NSERC expenditures shown in table 3.15, the category is flexible in terms of focus and responds to political and economic pressures, rather than peer committee evaluations, so it gives some impression of short-term government R&D priorities. The introduction of industrial materials and processes (which occurred in 1984) is notable, as is the increase for computing. Three categories, energy and oceans, which declined over the period shown, and food/agriculture, which did not, were droppe as strategic grant categories in 1987 but reintroduced in 1988. It appears that the resource-based research categories have declined in terms of strategic grant support, while the more high-tech categories have prospered.

Table 7.2 NSERC Total Research Base Grants[a], 1980/81 - 1986/87
(1981 $ thousand and percent)

Grant Selection Committee	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	% Change 1980/81-1987/88
Biology	27,773	29,049	30,650	31,591	33,426	33,484	35,086	36,025	29.7
Chemistry	16,680	17,679	19,164	18,552	17,264	16,525	17,639	16,851	1.0
Physics and space	19,223	21,591	20,031	20,913	19,147	8,639	26,115	25,205	34.5
Earth sciences	9,663	9,727	10,629	10,376	10,519	10,314	10,518	10,834	12.1
Mathematics, statistics, and computing	9,059	9,413	11,035	11,717	12,845	11,125	13,563	14,280	57.6
Engineering	26,443	28,673	29,449	32,721	33,572	34,275	36,058	35,533	34.3
of which: Mining and Metallurgy[b]	2,201	3,450	3,637	4,416	3,851	4,004	3,805	na	65.5[c]
Psychology	4,636	4,864	5,316	32,795	5,927	6,090	6,107	6,183	33.4
Interdisciplinary	696	1,085	1,046	703	748	801	908	783	12.5
Total	114,171	122,080	127,320	132,150	133,446	134,252	145,994	145,694	27.6

Source: NSERC, Report of the President, various years
[a] Excluding project grants.
[b] From table 3.18 and 3.19.
[c] 1980/81-1986/87.

Table 7.3 NSERC Total Research Base Grants, 1980/81 - 1986/87
(percent of total)

Grant Selection Committee	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88
Biology	24.3	23.8	24.1	23.9	25.1	24.9	24.0	24.7
Chemistry	14.6	14.5	15.1	14.0	12.9	12.3	12.1	11.6
Physics and space	16.8	17.7	15.7	15.8	14.4	13.9	17.9	17.3
Earth sciences	8.5	8.0	8.4	7.9	7.9	7.7	7.2	7.4
Mathematics, statistics, and computing	7.9	7.7	8.7	8.9	9.6	10.5	9.3	9.8
Engineering	23.2	23.5	23.1	24.8	25.2	25.5	24.7	24.4
of which: Mining and Metallurgy[b]	1.9	2.8	2.9	3.1	2.9	3.0	2.6	na
Psychology	4.1	4.0	4.2	4.2	4.4	4.5	4.2	4.2
Interdisciplinary	0.6	0.9	0.8	0.5	0.6	0.6	0.6	0.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: table 7.2.

Table 7.4 NSERC Strategic Grants, Selected Years
(1981 $ million and percent of total)

	1980/81		1981/82		1986/87		1987/88		% change 1980/81-1987/88
	$	%	$	%	$	%	$	%	
Energy	6.6	33.5	6.5	30.1	2.7	11.4	1.6	6.6	-76
Environmental toxicology	3.9	19.8	3.0	13.9	2.1	8.7	2.2	9.1	-3
Oceans	2.7	13.7	2.7	12.5	1.9	7.5	1.2	5.0	-55
Communications and computers	2.3	11.8	2.8	13.0	4.0	15.8	3.9	16.2	69
Food/agriculture	3.0	15.2	4.0	18.5	4.2	16.5	2.6	10.8	-13
Open	1.2	6.1	2.5	11.6	2.5	9.8	3.4	14.1	183
Biotechnology	0.0	0.0	0.0	0.0	2.9	11.4	3.6	14.9	na
Industrial material & processes	0.0	0.0	0.0	0.0	4.8	19.3	5.5	22.8	na
Total	19.7	100.0	21.6	100.0	29.3	100.0	24.1	100.0	22

Source: NSERC, Report of the President, 1986/87.

Graduate Student Enrollment

One measure of the level of R&D activity in universities which can be used for comparison is the number of graduate students, particularly PhD students. Table 7.5 shows total graduate enrollment by major discipline, and the changes from 1980/81 to 1985/86. A breakdown for selected natural sciences and engineering is provided in table 7.6.

Table 7.5 Full Time Graduate Enrollment by Field of Study 1980/81 - 1985/86

	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	% Change 1980/81 - 1985/86
Education	3,986	4,440	4,669	4,741	4,951	4,883	22.5
Fine & applied arts	993	1,038	1,064	1,130	1,101	1,144	15.2
Humanities	6,646	6,697	6,809	6,870	7,212	7,256	9.2
Social sciences	13,442	14,105	14,862	15,205	15,401	15,530	15.5
Agriculture & biological sciences	3,130	3,207	3,423	3,776	3,884	4,008	28.0
Engineering & applied sciences	3,692	3,962	4,694	5,724	5,931	5,619	52.2
Health professions	8,648	9,153	9,542	9,932	10,280	10,499	21.4
Mathematics & physical sciences	3,645	4,029	4,420	5,001	5,328	5,385	47.7
Other	476	490	565	666	562	287	-39.7
Total	44,658	47,121	50,048	53,045	54,653	54,611	22.3

Source: Statistics Canada 81-204.

Table 7.6 Full Time Graduate Enrollment in Natural Sciences and Engineering, 1980/81 - 1985/86

Discipline	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	% Change 1980/81 - 1985/86
Biology	2,015	2,008	2,116	2,332	2,441	2,524	25.3
Chemistry	1,015	1,122	1,191	1,310	1,366	1,405	38.4
Physics and space	747	781	853	961	1,037	1,030	37.4
Earth sciences	609	656	752	871	919	881	44.7
Mathematics, statistics, and computing	1,103	1,256	1,656	1,630	1,743	1,832	66.1
Engineering	3,121	3,370	4,075	5,031	5,237	4,968	59.2
of which: Mining and Metallurgy[a]	193	233	320	na	334	357	85.0
Psychology	1,914	1,962	2,081	2,209	2,355	2,412	26.0
Total	10,524	11,155	12,724	14,344	15,098	15,052	43.0

Source: Statistics Canada, 81-204.
[a] from table 7.13, which shows lower totals for engineering as a whole than shown here.

Table 7.7 Full Time Graduate Enrollment in Natural Sciences and Engineering, 1980/81 - 1985/86 (% of total)

Grant Selection Committee	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86
Biology	19.2	18.0	16.6	16.3	16.2	16.8
Chemistry	9.7	10.1	9.4	9.1	9.1	9.3
Physics and space	7.1	7.0	6.7	6.7	6.9	6.8
Earth sciences	5.8	5.9	5.9	6.1	6.1	5.9
Mathematics, statistics, and computing	10.5	11.3	13.0	11.4	11.6	12.2
Engineering	29.7	30.2	32.0	35.1	34.7	33.0
of which: Mining and Metallurgy	1.8	2.1	2.5	na	2.2	2.4
Psychology	18.2	17.6	16.4	15.4	15.6	16.0
Total	100.0	100.0	100.0	100.0	100.0	100.0

Source: table 7.6.

Discipline Comparison

It is interesting to compare percent change and percent share of NSERC grants by discipline, and of full-time graduate enrollment by the same discipline categories. This has been done in table 7.8. While direct parallels between graduate enrollment and NSERC research base support are not to be expected, because of differing research costs in different disciplines among other things, the contrasts are interesting. For example, engineering, which is a relatively high-cost research area, has 33 percent of graduate enrollment and only 25 percent of the research base funding. Chemistry funding has been brought closer into line with its graduate student proportion, dropping from 15 to 12 percent of total funding over the period shown, with virtually no funding increase in real terms. Not surprisingly, physics and space received about 2.5 times as much in funding (18 percent) as they contribute in proportion of graduate enrollment (7 percent), and psychology (which also receives support from the Social Sciences and Humanities Research Council) shows a reverse relationship. Mining and metallurgy combined receive approximately equal proportions in terms of the two measures. Mining alone, however, had 0.7 percent of graduate enrollment in 1985/86, and received only 0.1 percent of NSERC research base funding in that year.

Table 7.8 Summary of Natural Science and Engineering Discipline Comparisons

	Graduate Enrollment		NSERC Research Base Grants	
	% of Total 1985/86	% Change 1980/81-1985/86	% of Total 1986/87	% change 1980/81-1987/88
Biology	16.8	25.3	24.0	29.7
Chemistry	9.3	38.4	12.1	1.0
Physics and space	6.8	37.4	17.9	34.5
Earth sciences	5.9	44.7	7.2	12.1
Math, Stats and computing	12.2	66.1	9.3	57.6
Engineering	33.0	59.2	24.7	34.3
of which: Mining and metallurgy	2.4	85.0	2.6	72.9[a]
Psychology	16.0	26.0	4.2	33.4
Interdisciplinary	na	na	0.6	12.5
Total	100.0	43.0	100.0	27.6

Source: tables 7.2, 7.3, 7.6, and 7.7.
[a] 1980/81 - 1985/86.

MINING AND METALLURGY R&D IN UNIVERSITIES

R&D Funding

Table 7.9 provides information on R&D funding in mining and metallurgical engineering departments in Canadian universities. These data are derived from a survey of university departments undertaken in 1987-88. Unfortunately, the results are incomplete, as not all departments were able to provide the requested information. The results therefore understate the total level of funding.

Table 7.10 presents the CRS survey data for R&D funding by source of funds. In recent years, funding for the departments reporting to CRS was in the range of $9 million to $10 million per year, with half of the funds coming from NSERC. Other federal sources and provincial governments contributed similar amounts in 1986. In the mining category the provincial support is extremely high, higher than the combined federal sources. This is due to strong provincial support for the University of Alberta in the field of energy research and strong Quebec government support for the Ecole Polytechnique de Montreal.

Industry support for university mining and metallurgy R&D in the 1984 to 1986 period was in the range of 10 to 15 percent of total funding. Relative support for mining appears to have fallen since 1982 while support for metallurgy has remained fairly stable. In regard to the data shown in tables 7.9 and 7.10, it should be noted that some respondents suggested that the earlier years may have been underreported, since some of the earlier grants may have been overlooked or forgotten.

Table 7.11 repeats the NSERC research base totals for mining and metallurgy given in tables 3.18 and 3.19 in chapter 3, and compares them with the NSERC totals from the CRS survey in table 7.10. In spite of the low response rate, mining appears to be over-reported in the CRS survey. This is because some of the NSERC grants for mining research actually are coded within civil engineering categories which were not reported by NSERC as mining-related.

One notable development in university research in general has been the establishment of research centres known as "centres of excellence" within which positions of prestige, or Chairs, are held by prominent researchers who are leaders in the particular field. As of late 1988 a number of universities were attempting to establish such centres in mining or metallurgy. The Ecole Polytechnique and McGill University have created the Canadian Centre for Automation and Robotics in Mining (CCARM) with assurances of $200,000 per year from both the federal and provincial governments and commitments for equivalent funding from various mining

Table 7.9 R&D Funding of University Mining and Metallurgical Engineering Departments by University and Program, 1980-87
(1981 $ thousand)

University and Program	1980	1981	1982	1983	1984	1985	1986	1987
Toronto								
Metallurgy	1,112	1,749	1,038	1,242	1,299	1,405	1,205	na
Queen's								
Metallurgical	na	446	479	349	525	477	534	486
Mining	na	232	203	177	306	271	209	240
Laval								
Mining & metallurgical	557	508	355	593	758	1,054	1,023	1,001
McGill								
Mining and metallurgical	na	na	na	na	1,864	1,679	2,121	na
McMaster								
Metallurgical and materials science	600	980	1,219	1,418	1,824	1,450	1,678	na
Alberta								
Mineral	721	915	557	1,319	654	735	687	472
Ecole Polytechnique de Montreal								
Metallurgical	487	612	875	648	764	1,091	1,730	na
Mineral	1,105	924	393	462	772	835	827	na
Total	na	na	na	na	8,765	8,997	10,013	na

Source: CRS survey of universities.

Table 7.10 R&D Funding of University Mining and Metallurgy Departments, By Source of Funds, 1980-86
(1981 $ thousand)

Department and Source of Funds	1980	1981	1982	1983	1984	1985	1986
Mining[a]							
NSERC	na	363	282	282	375	345	329
Other Federal	na	na	98	364	146	380	293
Provincial	na	na	359	772	767	873	888
Industry	na	na	318	522	443	206	200
Other	na	na	95	17	1	37	13
Total	na	1,272	1,153	1,957	1,732	1,840	1,722
Metallurgy[b]							
NSERC	na	2,269	1,540	2,005	2,634	2,775	2,999
Other federal	na	606	759	708	774	544	852
Provincial	na	162	530	338	183	290	395
Industry	na	326	574	451	455	498	743
Other	na	424	211	154	366	316	158
Total	na	3,787	3,612	3,657	4,412	4,424	5,147
Mining/Metallurgy[c]							
NSERC	na	na	na	na	1,472	1,382	1,683
Other federal	na	na	na	na	683	324	553
Provincial	na	na	na	na	364	625	467
Industry	na	na	na	na	86	349	408
Other	na	na	na	na	17	52	33
Total	na	na	na	na	2,622	2,732	3,144
Total[d]							
NSERC	na	na	na	na	4,481	4,502	5,010
Other federal	na	na	na	na	1,603	1,248	1,698
Provincial	na	na	na	na	1,314	1,788	1,750
Industry	na	na	na	na	983	1,054	1,351
Other	na	na	na	na	384	405	205
Total	na	na	na	na	8,765	8,997	10,013

Source: CRS survey of university.
[a] Alberta, Queen's, Ecole Polytechnique.
[b] McMaster, Toronto, Queen's, Ecole Polytechnique.
[c] McGill, Laval.

firms (Noranda, Inco). The University of Calgary is attempting, less successfully, to establish a centre of excellence in surface mining. In Vancouver, the University of British Columbia has an Industrial Research Chair in Hydrometallurgy with funding of $250,000 to be contributed towards it by 10 Canadian companies over 5 years. Chairs in metallurgy have also been established at the University of Toronto and McGill. Rock mechanics studies are now supported by the creation of three chairs in a network involving the University of Toronto, Laurentian and Queen's Universities.

The Canadian government has recently created a program to provide funding for the development of Networks of Centres of Excellence with an emphasis on high quality research which is relevant to future competitiveness and which creates and encourages links between industry, university and government through collaborative research. The Mining Industry Technology Council of Canada has submitted a proposal for a mineral industry network with a focus on mining, mineral processing and extractive metallurgy. The network, if accepted, would involve researchers in nine core mining universities, six associate universities, CANMET and a number of major companies.

Table 7.11 Comparison of NSERC Research Base Funding Data and CRS Survey Data on NSERC Funding for Mining and Metallurgy, 1980-1986 (1987 $ thousand)

	1980	1981	1982	1983	1984	1985	1986
Mining							
CRS	na	363	282	282	375	345	329
NSERC	89	101	51	165	344	183	163
Metallurgy							
CRS	na	2,269	1,540	2,005	2,634	2,775	2,999
NSERC	2,591	3,842	4,011	4,804	4,713	5,334	4,954
Mining & metallurgy combined							
CRS	na	na	na	na	1,472	1,382	1,683
Total							
CRS	na	na	na	na	4,481	4,502	5,010
NSERC	2,680	3,943	4,062	4,969	5,057	5,517	5,117

Source: tables 3.18, 3.19 and 7.10.

NSERC Scholarships and Fellowships

Table 7.12 shows the number of NSERC scholarships and fellowships granted in recent years in mining and metallurgy. The number of scholarships in this combined field more than doubled in the period between 1981/82 and 1986/87, and has also risen as a proportion of all NSERC scholarships granted. The two major fields have usually been metallurgy and

Table 7.12 NSERC Scholarships and Fellowships in Mining and Metallurgy, Selected Years. (Number and Percent of Total)

Field	1981/82		1982/83		1984/85		1985/86		1986/87	
	Number	% of Total	Number	% of Total	Number	% of Total	Number	% of Total	Number	% of Total
Metallurgy	8	0.4	9	0.4	15	0.5	9	0.3	8	0.3
Metallurgical Engineering	5	0.2	5	0.2	1	0.0	5	0.2	12	0.4
Metallurgy and Materials Science	0	0.0	0	0.0	0	0.0	2	0.1	3	0.1
Mineral Engineering	1	0.0	0	0.0	3	0.1	5	0.2	4	0.1
Mining Engineering	0	0.0	1	0.0	3	0.1	1	0.0	1	0.0
Mining and Metallurgy	0	0.0	0	0.0	0	0.0	1	0.0	1	0.0
Materials Science	3	0.1	4	0.2	6	0.2	9	0.3	9	0.3
Total Mining and Metallurgy	17	0.8	19	0.9	28	1.0	32	1.2	38	1.2
Total all scholarships	2,046	100.0	2,174	100.0	2,867	100.0	2,732	100.0	3,107	100.0

Source: NSERC special compilation.

metallurgical engineering. The combined total of mining and metallurgy received 1.2 percent of the NSERC scholarships and fellowships in 1985/86, and had almost 2.4 percent of graduate enrollment in natural sciences and engineering.

Mining and Metallurgy Graduate Studies

Enrollment and degrees granted in graduate studies provide proxy measures of R&D intensity and focus that are more useful, for example, than number of faculty since some faculty positions involve only teaching and no research. Tables 6.20 and 6.22 in chapter 6 showed postgraduate degrees granted in mining and in metallurgy by university. In mining, the most active university is Queen's, with 41 percent all postgraduate degrees in Canada over the period 1981 to 1987. Total postgraduate degrees in mining varied widely over this period, from a low of 17 in 1982 to a high of 55 in 1987.

For metallurgy (table 6.22), distribution of effort is more widely dispersed, with the University of Toronto and McGill showing the largest numbers of graduates and University of British Columbia and Laval growing more rapidly and close behind. The total number of degrees is about double that in mining, and shows a more consistent pattern of increase, rising by 43 percent from 1981 to 1987. By far the largest proportion of degrees were at the Masters level (see tables 6.16 and 6.17). Looking at PhDs alone, however, metallurgy degrees outnumbered those in mining by about 7.6 to 1 over the period 1980 to 1987.

Table 7.13 looks at enrollment in graduate schools in engineering, using data provided by the Canadian Council for Professional Engineers. Unlike the CIM data in tables 6.20 and 6.22, it does not include metallurgy in Arts and Science; however, tables 6.16 and 6.17 indicate that this is not a significant omission. Here metallurgy enrollment (including materials engineering) is shown to be about four times that of mining. Both show very sharp jumps in 1982/83 which may reflect reduced job opportunities in that year. The much higher proportion of NSERC grants, relative to graduate enrollment, going to metallurgy is connected to the much larger proportion of PhD students in metallurgy graduate programs than in mining programs. While it is not clear whether low funding causes fewer PhD students in mining, or the reverse, it is clear that there is a relationship, and that the total research effort in mining is very small.

Table 7.13 Full-Time Graduate Enrollment in Engineering Programs in Canadian Universities, Selected Years

	1979/80	1980/81	1981/82	1982/83	1984/85	1985/86
Mining	43	44	44	74	85	83
Mineral	20	13	14	8	0	23
Metallurgical and materials	129	136	175	238	249	251
Geological	59	45	40	53	88	64
Aeronautical	65	61	65	70	88	83
Agricultural	43	46	54	69	104	111
Chemical	340	369	426	501	579	550
Civil	687	650	776	958	1,071	965
Computers	79	77	74	75	75	124
Electrical	678	690	811	1,064	1,323	1,250
Eng. & man.	28	34	37	38	43	90
Eng. Physics	42	28	40	52	57	53
Industrial	51	50	60	72	110	68
Mechanical	346	378	427	606	825	722
Survey	32	39	35	34	80	65
Systems	35	32	52	53	43	na
Other	16	220	183	209	307	225
Total	2,693	2,912	3,313	4,174	5,127	4,727

Source: Canadian Council of Professional Engineers; Engineering Manpower News, various years.

CONCLUSION

Overall funding of sponsored university research has grown significantly in this decade. NSERC is the major source of funding for research in the natural sciences and engineering and its total grants have also grown substantially. Mining and metallurgy NSERC grants have grown much more than have grants for any of the broadly defined NSERC grant categories. All of this growth is due to metallurgy since mining grants are negligible.

In terms of graduate student enrollment, which is a proxy for R&D activity, there has been a relative increase in the popularity of the natural sciences and engineering at the expense of the social sciences and humanities. Within the natural sciences and engineering, proportional enrollment in the natural sciences and psychology has fallen while it has risen in engineering, math and computer science. Graduate student enrollment in mining and metallurgy has grown at a much faster rate than has total graduate enrollment. Mineral-related R&D in Canadian mining and metallurgical engineering departments appears to have been at least $10 million in 1986. About half of this was provided by NSERC with a further one-third coming from other federal and provincial government sources. Industry does not appear to participate to any great extent in university mining and metallurgy R&D; it provided less than 15 percent of the funds in 1986.

The ratio of mining to metallurgy degrees granted reinforces the evidence of funding support which shows a much greater interest in research in metallurgy than in mining. At the undergraduate level, the ratio is about 1:1, with mining beginning to lag behind metallurgy. For all postgraduate degrees, the ratio is about 1:2. At the PhD level, the ratio is 1:5.

8. COMPARISON OF R&D EXPENDITURES IN OTHER RESOURCE SECTORS

INTRODUCTION

This chapter presents Statistics Canada data, plus some supplementary information, on R&D expenditures and sources of funds in the three major resource sectors in Canada: minerals (divided into petroleum and nonpetroleum), agriculture and forestry. For the purposes of comparison, it also provides data on the economic contribution of these sectors. Fisheries is included only as a subset of agriculture, because of its relatively small economic impact. (In 1984, for example, GDP for fisheries and trapping combined amounted to only 5 percent of agriculture GDP, 0.4 percent of GDP in goods-producing industries, and 0.1 percent of total Canadian GDP. See appendix table A.) The classification of the resource sectors by component industries and stage of production, based on the definitions of Anderson and Bennett, is shown in table 8.1.[1]

ECONOMIC CONTRIBUTION OF THE RESOURCE SECTORS

Gross Domestic Product

In general, the resource sectors of the Canadian economy have shown a decline in their share of total GDP over the past decade (see table 8.2). Over the period 1975-87 the forestry industry has remained relatively stable in its contribution while the agricultural sector has been characterized by a slow downward trend in its share. The share of the petroleum sector fell significantly in the second half of the 1970s and has fallen still further in this decade. Nevertheless, in 1987, petroleum contributed more to total GDP than any other resource sector (5.7 percent). The mineral sector has also experienced a decline in GDP share, although in 1987 it returned to its 1980 level. The overall decline to 1987 represents the tendency for resource commodity prices to remain constant, or increase at a slower rate than the general price index, over the long term, because of improved technology and productivity in those sectors on the one hand, and the growth of economic activity in the upstream higher value-added sectors in manufacturing on the other hand (see appendix table A.3 for comparisons of price indices). This unavoidable economic reality was accentuated for Canadian resource producers in the period between 1975 and to 1987 because of their

1. D.L. Anderson and T. Bennett, An Inter-Sectoral Study of Canada's Resource Industries, (Kingston: Centre for Resource Studies, 1988).

Table 8.1 Classification of Resource Sectors by Component and Stage of Production

	Sector							
	Minerals		Petroleum		Agriculture		Forestry	
Stage	Description	SIC Code	Description	SIC Code	Description	SIC Code	Description	SIC Code
Primary	Metal mines	061	Crude petroleum and natural gas	071	Farming	01	Logging	04
	Nonmetal mines	062			Fishing	031	Services incidental	05
	Coal mines	063			Trapping	033		
	Quarries etc.	081-2	Services incidental to mining	09	Services incidental	02		
Processing	Primary steel	291	Refined petroleum and coal products	36	Food	10	Wood	25
	Nonferrous smelting and refining	295			Beverages	11		
					Tobacco	12		
					Leather	17		
Fabricating	Primary metal (excluding processing stage)	29	n/a		n/a		Pulp and paper	27
	Wire	305						
	Nonmetallic mineral products	35						
Totals	Total minerals	all the above	Total petroleum	all the above	Total agriculture	all the above	Total forestry	All the above

Source: Anderson and Bennett, An Inter-Sectoral Study of Canada's Resource Industries, (Kingston, Centre for Resource Studies, 1988).

Table 8.2 Contribution of Resource Sectors to GDP, Selected Years
(1981 $ billion and percent of GDP)

	1975		1980		1983		1987	
	$	% of GDP	$	% of GDP	$	% of GDP	$	% of GDP
Minerals								
Primary	6.3	2.4	6.6	2.2	5.5	1.7	8.4	2.2
Processing	4.0	1.6	3.7	1.2	3.5	1.1	4.6	1.2
Fabricating	3.9	1.5	3.6	1.2	3.0	0.9	3.6	1.0
Total	**14.3**	**5.5**	**14.0**	**4.5**	**12.0**	**3.8**	**16.6**	**4.4**
Petroleum								
Primary	21.8	8.5	13.5	4.4	12.6	4.0	13.4	3.5
Processing	0.9	0.3	0.7	0.2	0.8	0.3	0.8	0.2
Total	**22.7**	**8.8**	**14.3**	**4.6**	**13.4**	**4.2**	**14.2**	**3.7**
Agriculture								
Primary	10.1	3.9	10.2	3.3	11.5	3.6	12.1	3.2
Processing	7.9	3.1	8.9	2.9	8.5	2.7	9.4	2.5
Total	**17.9**	**7.0**	**19.1**	**6.2**	**20.1**	**6.3**	**21.6**	**5.7**
Forestry								
Primary	1.6	0.6	2.1	0.7	2.2	0.7	2.8	0.7
Processing	2.2	0.8	3.1	1.0	3.0	0.9	4.4	1.2
Fabricating	4.8	1.9	6.2	2.0	5.8	1.8	6.5	1.7
Total	**8.6**	**3.3**	**11.4**	**3.7**	**11.0**	**3.5**	**13.7**	**3.6**
All resource sectors	63.5	24.7	58.8	19.1	56.4	17.7	66.1	17.4
Total GDP	257.5	100.0	307.4	100.0	317.9	100.0	379.2	100.0

Source: Statistics Canada, 15-001, and 15-511.

dependence on export markets, and because, for a wide variety of reasons, they changed from being major suppliers in a resource-hungry world to just more competitors in over-supplied resource markets.

It seems likely that Canada's access to foreign markets will continue to be threatened by increasing self-sufficiency in resource production in third-world countries, increasing competition in industrial markets from the same third-world producers, and changing demand patterns due to down-sizing and substitution. The present level of production of all the resource sectors in Canada is far beyond Canada's domestic requirements. Maintaining these sectors with some degree of economic strength will require R&D efforts that may appear to be out of proportion to the overall domestic economic importance and stage of maturity of the sectors in order to continue to improve productivity and competitiveness in international markets.

Exports

Resource commodities play a major role in Canada's exports, much greater than their contribution to GDP, because domestic production far exceeds domestic consumption. However, table 8.3 indicates that resource-based commodities have fallen in terms of percent of total export commodities from over 60 percent in 1980 to 46 percent in 1986, a drop of almost 25 percent. Minerals and forestry are similar in terms of value of exports, while petroleum and agriculture combined represented about 40 percent of all resource sector exports.

Employment

In employment, the resource sectors show more variation in terms of economic impact (see table 8.4). For instance, the GDP output per employee for 1980 is as follows:

- petroleum - $202 thousand;
- minerals - $46 thousand;
- forestry - $38 thousand;
- agriculture (using an estimated labour force of 700,000) - $27 thousand.

In terms of total employment, in contrast, agriculture provides the largest percent, and petroleum the smallest. However, in terms of regional employment contribution, minerals and forestry play much more significant roles in remote areas, where many communities are dependent on the resource industries for their economic base. A study for the Provincial Mines Ministers, for example, found that 74 communities in Canada with a total population of over 530,000 were dependent on mining in 1984.[2] An earlier federal study identified over 800 single-industry communities in Canada, of which 142 were dependent on mines and refineries, 302 on wood, and 131 on fish and fish processing. Only 9 were identified as agricultural service centres, and 31 as dependent on food processing.[3]

Table 8.3 Contribution of Resource Sectors to Exports, Selected Years, (1981 $ billion and percent of total)

	1980		1983		1986	
	$	%	$	%	$	%
Minerals	17	20.4	9	14.8	15	15.5
Petroleum	10	12.0	9	11.3	7	7.0
Agriculture	10	12.3	10	12.7	9	9.3
Forestry	14	16.6	11	14.5	14	14.5
Resource sector commodities	52	61.4	42	53.3	45	46.3
All Canadian export commodities	85	100.0	79	100.0	96	100.0

Source: Anderson and Bennett, An Inter-Sectoral Study of Canada's Resource Industries, Technical Paper No. 8 (Kingston: CRS, 1988).

2. Energy and Mines Manitoba and EMR, New Financial Mechanisms for Addressing Mining Community Problems, (Ottawa: 1985).
3. Department of Regional Economic Expansion, Single Industry Communities, (Ottawa: 1977).

Table 8.4 Employment in the Resource Sectors, Selected Years (thousand employees)

	1975	1980	1984	1985
Minerals				
primary	97.7	99.0	81.8	77.7
processing	89.6	97.4	85.5	78.2
fabricating	104.3	105.8	90.2	94.5
total	**291.6**	**302.1**	**257.5**	**250.4**
Petroleum				
primary	29.2	50.8	62.1	69.6
processing	17.3	20.1	17.3	16.7
total	**46.5**	**70.9**	**79.4**	**86.3**
Agriculture				
processing	256.9	267.6	250.7	254.1
Forestry				
primary	53.6	54.4	48.0	46.0
processing	97.1	117.3	102.9	107.6
fabricating	127.3	130.3	115.8	114.2
total	**278.0**	**302.0**	**266.7**	**267.8**

Source: Statistics Canada, 25-202, 26-201 and 31-203.
Note: Primary agricultural employment information is not available in the Statistics Canada industrial data series. According to the Statistics Canada Labour Force Survey, 1985 total employment in agriculture and fishing was 768,000, compared with 300,000 in forestry. This would suggest primary employment in agriculture was over 400 thousand.

R&D IN THE RESOURCE SECTORS: STATISTICS CANADA DATA

Statistics Canada does not publish any data series on gross R&D expenditures (GERD) for all of Canada by industrial sector. Expenditure data are published in two principal categories: federal government expenditures (in catalogue 88-204) and industry in-house R&D expenditures (in catalogue 88-202). Except for some information on provincial contributions to in-house industry R&D and on provincial in-house research organizations, there is no compilation of provincial R&D expenditures. This chapter will therefore look at industry and federal expenditures separately for the resource sectors, and supplement the Statistics Canada data with selected but scanty information on other aspects including provincial R&D support.

Table 8.5 Total Industry Intramural R&D Expenditures, 1980-1987, by Resource Sector
(1981 $ million)

	1980	1981	1982	1983	1984	1985	1986	1987	% Change 1980-1987
Minerals[a]									
primary	31	51	44	38	40	42	39	38	22.6
processing	118	110	100	91	102	98	91	104	-11.9
fabricating	24	30	34	33	34	41	38	42	7.5
total	**173**	**191**	**178**	**162**	**176**	**181**	**168**	**184**	**6.4**
Petroleum									
primary	80	80	78	43	57	56	30	24	-70.0
processing	179	272	225	161	185	168	118	103	-42.5
total	**259**	**352**	**303**	**204**	**242**	**224**	**148**	**127**	**-51.0**
Agricultural									
primary and processing	55	56	67	61	60	65	70	67	21.8
total	**55**	**56**	**65**	**61**	**60**	**65**	**70**	**67**	**21.8**
Forestry									
primary and processing	15	15	13	13	15	17	17	18	20.0
fabricating	58	68	57	49	54	61	70	65	12.1
total	**73**	**83**	**70**	**62**	**69**	**78**	**87**	**83**	**13.7**
Total resource sector	560	682	616	489	547	548	473	461	-17.7
Total all industry	1,742	2,125	2,289	2,265	2,537	2,974	3,055	3,174	82.2

Source: Statistics Canada, 88-202.
[a] Because the data could not be disaggregated, the mineral processing industry here incorporates the complete primary metal industry (SIC 29), while mineral fabricating includes non-metallic mineral products and all of metal fabricating (SIC 30).

Industry R&D Expenditures

Table 8.5 compares the four resource sectors in terms of industry intramural R&D expenditures in 1981 dollars, and shows the percent change over the period 1980 to 1987. Table 8.6 shows the relative contribution by sector to total industry R&D expenditures.

Table 8.6 Percent Share of Total Industry Intramural R&D Expenditures By Resource Sector, 1980-1987

	1980	1981	1982	1983	1984	1985	1986	1987
Minerals								
primary	1.8	2.4	1.9	1.7	1.6	1.4	1.3	1.2
processing	6.8	5.2	4.4	4.0	4.0	3.3	3.0	3.3
fabricating	1.4	1.4	1.5	1.5	1.3	1.4	1.2	1.3
total	**9.9**	**9.0**	**7.8**	**7.2**	**6.9**	**6.1**	**5.5**	**5.8**
Petroleum								
primary	4.6	3.8	3.4	1.9	2.2	1.8	1.0	0.7
processing	10.3	12.8	9.8	7.1	7.3	5.6	3.9	3.2
total	**14.9**	**16.6**	**13.2**	**9.0**	**9.5**	**7.5**	**4.8**	**4.0**
Agricultural								
primary and processing	3.1	2.6	2.8	2.7	2.4	2.2	2.3	2.1
total	**3.1**	**2.6**	**2.8**	**2.7**	**2.4**	**2.2**	**2.3**	**2.1**
Forestry								
primary and processing	0.9	0.7	0.6	0.6	0.6	0.6	0.6	0.6
fabricating	3.3	3.2	2.5	2.2	2.1	2.1	2.3	2.0
total	**4.2**	**3.9**	**3.1**	**2.7**	**2.7**	**2.6**	**2.8**	**2.6**
Total resource sector	32.1	32.1	26.9	21.6	21.6	18.4	15.5	14.5
Total all industry	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: table 8.5.

Comparing the contribution of each sector to total industry intramural R&D and total GDP in 1987 (from table 8.2) is instructive. The petroleum industry shows similar ratios: both have fallen over the period 1980-87, but the industry share of R&D has fallen much more substantially. A similar pattern is evident in the mineral sector, although the R&D share still remains much higher than GDP share. Both the mineral and petroleum sectors contribute a larger share to total R&D than they do to total GDP. The reverse is true of forestry and agriculture; although the

latter is the most important resource sector in terms of GDP contribution, it nevertheless makes the smallest contribution to R&D of any resource sector.

Current intramural R&D expenditures (i.e. total R&D minus R&D capital expenditures) are shown in table 8.7, and as a percent of sales in table 8.8. This ratio can be considered as equivalent to national comparisons of R&D expenditures as a percent of GDP. All of the resource sectors are below the average R&D intensity for Canada, and well below the minimum that is generally recognized as necessary to generate the improvements in productivity that are needed to maintain competitive position in technologically intensive industries.[4]

Table 8.7 Current[a] Intramural R&D Expenditures by Resource Sector Companies, 1980-87
(1981 $ million)

	1980	1981	1982	1983	1984	1985	1986	1987	1988
Minerals[b]	139.5	166.0	160.7	148.7	157.1	161.8	150.2	160.2	165.9
Petroleum	186.0	279.0	208.4	154.0	158.8	149.5	131.2	114.6	118.4
Agriculture	48.8	51.0	56.0	54.2	53.2	53.9	59.6	58.8	58.1
Forestry	66.4	68.0	61.5	57.7	61.7	66.2	70.0	74.3	74.7

Source: Statistics Canada 88-202.

a Current = total minus capital R&D expenditures. Current is considered a better measure for examining trends and analyzing relationships with other economic variables.

b because the data could not be disaggregated, the mineral processing industry here incorporates the complete primary metal industry while mineral fabricating includes nonmetallic mineral products and all of metal fabricating.

4. For example, technologically intensive industries report R&D expenditures in excess of 10 or 15 percent of revenues. See table 5.11.

Table 8.8 Current Intramural Company R&D Expenditures as Percent of Sales, within Resource Sector, 1981-1986

	1981	1982	1983	1984	1985	1986
Minerals[a]						
primary	0.8	1.1	0.8	0.7	0.9	0.7
processing (ferrous)	0.3	0.4	0.3	0.3	0.3	0.4
processing (nonferrous)	0.7	0.9	1.2	1.3	1.4	1.3
fabricating(metal)	0.6	0.9	0.9	1.0	1.1	1.2
fabricating (non metal)	0.4	0.4	0.4	0.5	0.5	0.5
Petroleum						
primary	0.6	0.6	0.6	0.8	0.6	0.6
processing	0.8	0.6	0.4	0.4	0.5	0.5
Agriculture						
primary and processing	0.3	0.3	0.4	0.4	0.4	0.4
Forestry						
primary and processing	0.2	1.2	0.5	1.4	0.8	0.6
fabricating	0.4	0.4	0.4	0.3	0.3	0.3

Source: Statistics Canada, 88-202.

[a] because the data could not be disaggregated, the mineral processing industry here incorporates the complete primary metal industry while mineral fabricating includes nonmetallic mineral products and all of metal fabricating.

Table 8.9 Sources of Industry Funds for Intramural R&D, by Resource Sector, 1986
(1981 $ million)

	Canadian Performing Company	Federal Government	Other Canadian Sources	Foreign Sources	Total
Minerals[a]					
primary	31.0	x	2.4	x	39.0
processing					
ferrous	21.5	x	x	x	21.5
nonferrous	23.8	0.8	x	x	70.0
fabricating	31.0	4.0	x	x	39.0
Petroleum					
primary	11.9	x	16.7	x	29.4
processing	111.3	x	4.0	x	116.8
Primary minerals plus primary petroleum	42.9	x	19.1	x	68.4
Agriculture primary and processing	62.8	4.0	2.4	0.8	70.0
Forestry					
primary and processing	3.2	7.2	x	x	17.5
fabricating	50.1	2.4	x	x	69.2

Source: Statistics Canada 88-202.
[a] Because the data could not be disaggregated, the mineral processing industry here incorporates the complete primary metal industry while mineral fabricating includes nonmetallic mineral products and all of metal fabricating.

Limited information is available on sources of funds for intramural R&D in industry. Table 8.9 shows wide ranges in industry self-sufficiency in R&D funding in 1986, from 18 percent for forestry processing to 95 percent for petroleum processing. The information in this table may be misleading: the relatively poor figures for forestry and mineral processing in terms of "own funds" contribution reflect in part Statistics Canada's use of the "establishment" (a single factory, mine or office) as the basic unit of production rather than the firm or company. This ignores the interrelationships within multinationals and vertically and horizontally integrated firms, and therefore fails to reflect R&D expenditures moving between establishments within companies or corporate groups.

Federal Government R&D Expenditures

The Statistics Canada data series on federal R&D activities (catalogue 88-204) do not identify expenditures by resource sector per se. Furthermore, although the departmental Annual Reports do give some breakdown of expenditures by program that can be assigned to specific resource sectors, they do not identify R&D expenditures within programs. (See table 3.2 for R&D expenditure by department). It is therefore difficult to give a comparison of federal R&D expenditures in the various resource sectors. However, other indications of interest and funding trends are available.

Table 8.10 shows federal R&D by area of application, indicating that there has been little change in the R&D focus, by these classifications at least, since 1980/81. Natural resources have seen a small decline in overall share of federal R&D funding, while agriculture's share increased in 1984-1987. Table 8.11 shows federal line department R&D expenditures related to natural resources. Again, comparison with table 8.2 is interesting. Agriculture, which accounts for 5.7 percent of GDP in 1987 receives 14 percent of federal R&D support in sciences and engineering in 1987/88, in the category of food (including agriculture and fisheries). Minerals and forestry have a combined GDP share of 8 percent, while natural resources (including minerals and forestry) receives only 6 percent of federal R&D support. Energy (which would include coal, nuclear and nonconventional sources as well as oil and gas) received 11 percent of the federal R&D funding, while the petroleum sector accounted for only 3.7 percent of GDP. Although none of the categories are strictly comparable between the two tables, it does appear that agriculture's share of federal funding is extremely large, when compared to its GDP share.

Table 8.10 Federal R&D Spending in Natural Sciences and Engineering by Area of Application, 1980/81 - 1987/88 (Percent)

Application Area	1980/81	81/82	82/83	83/84	84/85	85/86	86/87p	87/88p
Advancement of science	14	14	14	14	14	15	16	17
Communications	3	3	3	4	3	3	3	2
Energy	16	14	15	15	14	12	11	11
Environment	3	4	4	4	2	2	2	2
Food (including agriculture & fisheries)	13	14	14	14	16	17	16	14
Health	10	9	9	9	9	9	10	10
Industrial support	11	13	11	11	13	14	16	17
Natural resources (including minerals and forestry)	7	7	7	7	6	6	6	6
Oceans	2	4	3	3	3	3	2	2
Security	8	8	8	8	9	9	9	10
Space technology	5	4	4	2	3	2	2	1
Transportation	3	3	3	4	3	3	3	3
Other	5	5	6	6	5	5	4	5
Total (%)	100	100	100	100	100	100	100	100
(1981 $ million)	1,373	1,507	1,603	1,766	1,923	1,865	1,839	1,776

Source: Statistics Canada, 88-204.

Table 8.11 Summary of Selected Federal Government Resource-Related Line Department R&D Expenditures, 1980/81 - 1987/88 (1981 $ million)

Department	1980/81	81/82	82/83	83/84	84/85	85/86	86/87p	87/88p
EMR total	138.1	153.5	156.5	169.0	189.9	213.8	192.4	189.9
Agriculture and forestry total[a]	179.5	186.5	191.9	273.6	293.8	300.1	289.2	273.3
Fisheries and Oceans total	90.3	92.0	101.7	115.2	122.1	121.2	106.7	86.3

Source: Statistics Canada 88-204; CANMET Research Program Office.
Note: Totals may not match component totals because of different sources, inclusion of management and service, missing components, etc.
a Canadian Forestry Service (CFS) R&D expenditures included from 1983/84 on. CFS R&D expenditures were $50.9 million, $57.4 million and $62.8 million in 1984/85, 1985/86 and 1986/87, respectively.

In 1985 the Ministry of State for Science and Technology made an attempt to compare federal R&D expenditures to resource sector economic contributions, and the results are shown in table 8.12. This table was prepared as preliminary work for a background study,[5] and is presented here only as an indication of the data and analytic difficulties involved, not as a published research conclusion. It is clear that the approach, categories, and numbers are quite different than those in this study, although the purpose is fundamentally similar. The MOSST findings also support the evidence in table 8.11 that federal R&D support for agriculture (and even more so for fisheries) is large, relative to the sector's overall financial contribution. The mineral sector's ratio of federal support to sector sales is the smallest among the resource sectors, according to the MOSST findings.

Table 8.12 Federal R&D Expenditures as Percent of Resource Sector Sales (undated)

	Federal R&D Expenditures ($ million)	Sales of Product[a] ($ billion)		Ratio of R&D to Sales (%)
Forestry	45.5	(P)	4.4	0.16
		(P+S)	28.6	
Fisheries[b]	53.8	(P)	2.0	2.70
Agriculture	164.8	(P)	5.3	0.48
		(P+S)	34.2	
Crude Petroleum and natural gas[c]	92.7	(P)	24.0	0.18
		(P+S)	52.1	
Metals[d]	48.1	(P)	10.4	0.12
		(P+S)	39.7	

Source: MOSST, draft: Background to a Study of The Potential For New Technologies in the Resource Sectors,(Ottawa: March 1985).
(P) - Primary outputs (P+S) - Primary plus secondary outputs.

[a] represents sales calculated from income tax returns, except for forestry which is based on the value of production.
[b] includes wildlife.
[c] earth sciences research has been assigned entirely to petroleum.
[d] includes some non-metallic mineral products.

5. MOSST, Draft: Background to a Study of the Potential for New Technologies in the Resource Sectors,(Ottawa: March 1985).

R&D IN THE RESOURCE SECTORS: MISCELLANEOUS DATA

Introduction

Detailed information on the mineral sector is provided throughout this study. This section of chapter 8 looks at miscellaneous data collected from sources other than Statistics Canada, to supplement the earlier section of this chapter, for the petroleum, agricultural and forestry sectors, and for earth sciences, which in large part serves the exploration stages of the mining and oil and gas industries.

Petroleum Industry R&D Data

The petroleum industry in Canada consists of three types of firms:

- multinationals, which comprise a few large firms;
- Canadian-owned companies most of which are medium-sized;
- juniors - Canadian-owned firms - consisting of small companies, mainly nonproducers.

The multinational companies and a few Canadian firms, including Petro-Canada, are integrated extractors, refiners, and retailers, with activities in both the upstream (exploration, development and production) and downstream (refining, processing and marketing) sectors of the industry. In 1985 there were 913 firms in the industry, of which 348 were located in Alberta. The downstream portion is highly concentrated, with the leading four enterprises in the petroleum and coal products industry accounting for 67.9 percent of the sales and 92.6 percent of the profits. Tables 8.13 and 8.14 give some descriptive statistics of the petroleum industry in Canada.

The Petroleum Monitoring Agency (PMA) is a federal agency which monitors the activities of about 100 producing companies representing about 90 percent of the industry. Table 8.14 presents PMA data on petroleum industry upstream capital expenditures, converted to 1981 dollars. The most obvious feature of the data is the downturn in 1981 and 82, and the even sharper decline in 1986, a result of the price drop in oil during that year, and accentuated by the 50-percent decline in federal assistance grants.

Data on oil and gas industry R&D activities related to the combined category of exploration and production are compiled from survey information collected by the Petroleum Monitoring Agency (PMA), as shown

in table 8.15. R&D in this survey excludes items such as prospecting and exploratory drilling, the development of oil and gas wells, and pilot/demonstration plants to develop commercial technology.
In-house R&D expenditures represent an average of approximately 85 percent of total R&D spending for the industry over the period examined; in-house exploration and production R&D fell from 44 to 16 percent of the total, between 1980 and 1987, a drop of 81 percent. In-house R&D expenditures by the petroleum industry during 1986 were equal to 0.6 percent of sales, well below the average for all other non-financial industries, which was 1.4 percent (see table 5.11). Contract R&D declined from $29 million in 1980 to $12 million in 1987, a drop of 59 percent.

Statistics Canada, in its industrial research statistics, reports very different figures for crude petroleum and natural gas industry R&D expenditures, as shown in table 8.16. (In this survey only 14 oil and gas producers and one contract drilling company reported R&D expenditures, unlike the PMA survey in which 25 companies reported R&D in 1987 and 28 in 1986). While this data series shows smaller absolute figures, the decline from 1981 is still severe. However, the table also supports the observations that the peaks in R&D expenditure in 1981 and 1985 were short-lived. Before one takes these data too seriously, particularly the forecasts, it would be wise to look at table 8.17 as well, which shows how the numbers have been changed (without published explanation) during the course of Statistics Canada revisions.

Table 8.13 Statistical Profile of the Canadian Petroleum Industry, 1980 - 1987

	Units	1980	1983	1985	1986	1987p
Employees[a]	number	27,448	33,418	34,108	32,700	na
Value of O&G production	1981 $ billion	18.8	19.5	21.0	12.2	12.5
Value of O&G exports	1981 $ billion	7.8	6.6	8.2	5.0	na
Upstream capital expenditures[b]	1981 $ billion	7.7	5.9	7.6	5.0	4.2

Source: Petroleum Monitoring Agency Canada, Monitoring Survey, selected years.
[a] over 90 percent located in Alberta.

Table 8.14 Petroleum Industry Upstream Capital Expenditures in Canada, 1980 - 1987
(1981 $ million)

	1980	1981	1982	1983	1984	1985	1986	1987
Land Lease, Geology and Geophysics	1,771	1,312	1,011	1,042	1,377	1,408	854	1,034
Exploration Drilling	2,808	2,536	2,296	2,702	2,827	2,619	1,747	1,056
Development Drilling	1,147	1,093	899	842	950	1,240	833	779
Production	1,213	1,423	1,379	977	1,069	1,395	1,075	957
Non-Conventional	728	532	353	374	495	924	478	424
Total Upstream	7,667	6,896	5,938	5,937	6,718	7,587	4,987	4,252

Source: Petroleum Monitoring Agency Canada, Monitoring Survey, various years.

Table 8.15 R&D Expenditures in Canada in Upstream, PMA Reporting Companies 1980 - 1987
(1981 $ million)

	1980	1981	1982	1983	1984	1985	1986	1987
In-house:								
Exploration & Production[a]	104	118	89	68	47	29	25	20
Surface mining[a]	na	36	20	7	6	6	2	6
In-situ production	102	120	101	41	40	92	43	27
Refining[a]	na	39	59	51	53	53	46	42
Other	19	33	34	25	25	29	16	15
Total in-house	225	346	303	192	171	209	133	111
Contract Research in Canada:								
Parents & affiliated companies	na	10	9	15	18	21	10	9
Other corporations	24	56	13	8	15	7	2	2
Research institutions	4	3	3	2	2	4	3	1
Total contract	29	69	25	24	35	32	16	12
Total Canada	254	415	328	216	206	241	149	123

Source: Petroleum Monitoring Agency Canada, Annual Report, various years.
[a] Refining and surface mining included with exploration and production in 1980.

Table 8.16 Crude Petroleum and Natural Gas Industry Intramural R&D Expenditures, selected years
(1981 $ million)

	1978	1981	1983	1985	1987	1988[p]
Current	37	46	29	38	21	20
Capital	8	34	14	19	3	5
Total	45	80	43	56	24	25

Source: Statistics Canada, 88-202.

Table 8.17 Total Intramural R&D Expenditures, Crude Petroleum and Natural Gas, 1975 - 1988 (current $ million)

	1984 Series	1987 Series	1988 Series
1975	33		
1976	28		
1977	35		
1978	38	33	33
1979	89	71	71
1980	100	72	72
1981	121	80	80
1982	124	85	85
1983	136	49	49
1984	132	68	67
1985		75	69
1986		54	37
1987		56	31
1988			33

Source: Statistics Canada, 88-001, various issues.

Earth Science R&D Activities

Introduction

This section includes information on the larger category of "science and technology" (S&T) activities, as well as its two subsets, "related scientific activities" (RSA) and R&D. Activities in earth sciences that are classified as RSA in Canada include geological surveys and mapping and the resulting publications conducted by the federal and provincial geological surveys. It is sometimes argued that these activities, along with the mineral exploration activities conducted by the private sector, are analogous to R&D in the manufacturing sector, since they provide the new resources and raw materials for the primary minerals industry. This study does not enter into the definitional debate on what constitutes R&D in the mineral industry. Instead, some data on mineral exploration expenditures by industry are provided separately from R&D data in chapter 5, and this section provides information on federal and provincial expenditures on earth science S&T, particularly geoscience data collection and information services. It should be noted that these activities support both the mining and the petroleum sectors.

Federal Earth Science Activities

Federal earth science activities are found principally within the Geological Survey of Canada, which since 1986 has included the Earth Physics Branch of EMR and since 1987 has included the Polar Continental Shelf Program. Some earth-science related activities are also funded by the Canada Centre for Remote Sensing. However, separate financial data on the earth-science components of this program are not available.

The Geological Survey of Canada (GSC) was founded in 1842 and has the following basic responsibilities:

- to ensure the availability of a comprehensive basic knowledge of the Canadian landmass, including the offshore areas;
- to acquire geological information on the nature and distribution of Canadian mineral and energy resources;
- to identify and assess the natural geological hazards, features, and processes that affect the environmental and ecological balance that may constrain the use of the land, particularly in association with resource exploration, development and utilization.

The mandate of the Earth Physics Branch has been to ensure the availability of geophysical information and expertise concerning the solid earth and to operate the Canadian network of seismological, geomagnetic and geodynamic observation stations.

In 1987, the GSC became a sector within EMR, as part of that department's reorganization, adding the Polar Continental Shelf Project to its former eight divisions, which were combined to form four branches: Sedimentary and Marine Sciences; Continental Geoscience and Mineral Resources; Geophysical Survey, Hazards and Terrain Sciences Branch; and headquarters.

Total expenditures by activity for the newly-organized GSC are shown in table 8.18 for 1986/87. In 1985/86, GSC estimated that its expenditures on R&D related specifically to mineral exploration technology and techniques (as opposed to basic geoscience R&D) were approximately $17 million in 1981 dollars, or 31 percent of the total R&D expenditures of $55 million.1

1. R. Price, GSC, personal communication, 21/11/85.

Table 8.18 Geological Survey of Canada Sector Expenditures by Activity, 1986/87
(current $ thousand)

	Operating and Personnel	Capital	Contributions	Total	Percent of Total
Sedimentary & Marine Geoscience					
Cordilleran & Pacific	6,793	961	0	7,754	7.0
Sedimentary & petroleum	14,252	1,376	0	15,628	14.2
Atlantic Geoscience Centre	13,890	1,370	0	15,260	13.8
Total	34,935	3,707	0	38,642	35.0
Continental Geoscience and Mineral Resources					
Mineral Resources	14,079	709	0	14,788	13.4
Lithosphere & Canadian Shield	9,535	172	0	9,707	8.8
Total	23,614	881	0	24,495	22.2
Geophysical Surveys, Hazard and Terrain Sciences					
Geophysics	12,434	2,274	0	14,708	13.3
Terrain Sciences	9,336	349	0	9,685	8.8
Total	21,770	2,653	0	24,393	22.1
Programs, Planning & Services					
Geoscience Information	4,636	94	0	4,730	4.3
Planning, common services and special projects	5,339	543	0	5,882	5.3
Total	9,975	637	0	10,612	9.6
Polar Continental Shelf Project	6,012	711	0	6,723	6.1
Sector Headquarters	825	15	4,605	5,445	4.9
Total GSC Sector	97,131	8,574	4,605	110,310	100.0
Total GSC Sector 1981 $	77,211	6,816	3,661	87,687	

Source: GSC, Annual Report, 1986/87.

Virtually all of the federal earth science expenditures are classified as S&T, as can be seen by comparing the total in 1981 dollars in table 8.18 with the 1986/87 total in table 8.19. Table 8.19 also indicates that S&T funding for earth sciences increased by 49 percent in real terms over the period shown, and the R&D component increased by 58 percent.

Table 8.19 EMR Funding of Earth-Science Related S&T, 1982/83 - 1986/87 (1981 $ million)

	1982/83	1983/84	1984/85	1985/86	1986/87[a]
Geological Survey of Canada:					
R&D	38.6	40.6	49.9	54.9	70.8
RSA	7.9	7.9	7.8	10.9	15.7
S&T total	46.5	48.5	57.7	65.8	87.5
Earth Physics					
R&D	6.1	6.5	7.6	7.3	na
RSA	6.2	6.3	7.8	7.8	na
S&T total	12.3	12.8	15.4	15.2	na
Total GSC and EP S&T	58.8	61.3	73.1	81.0	87.5

Source: EMR Expenditures in the Natural Sciences, Science Addendum to the Main Estimates, various years.

[a] In 1986 the Earth Physics Branch was incorporated into the Geological Survey.

However, these figures are misleading, in terms of real long-term trends. Since capital expenditures are irregular, and personnel costs are largely fixed by the number of in-house permanent staff, operating funds give the best indication of trends in the ability of the GSC to fund its on-going activities. In 1986/87, operating funds accounted for about 43 percent of the GSC's total resources. However, less than half of the operating funds were derived from the A-base, or continuing long-term budget of the GSC. The majority of the operating funds came from add-on funding programs, either sunset programs which have a fixed expiry date, or renewal programs subject to abrupt termination if they are not renewed. Table 8.20 shows that the operating A-base of GSC has in fact declined by 25 percent in real terms over the period 1982/83 to 1986/87.

Furthermore, GSC projections indicate a further decline of 17 percent in the A-base to 1992/93. Their "worst case" scenario projection shown in table 8.21 predicts that the sunset programs, all of which are scheduled to expire between 1986/87 and 1990/91, will not be renewed, leaving only the Energy R&D program in addition to the A-base. This would result in a drop to $12.7 million in 1981 dollar terms by 1992/93. There is some uncertainty over whether or not the energy R&D funding will in fact be renewed. On the other hand, there is some interest, particularly in eastern Canada, in a new generation of MDA agreements. Furthermore, new sunset programs may arise in response to new political and economic priorities. In the meantime, the GSC has already moved to trade some of its personnel funding resources for capital and operating funds.

Table 8.20 Geological Survey of Canada, Total Operating Resources by Source, 1982/83 - 1986/87
(1981 $ thousand)

	1982/83	1983/84	1984/85	1985/86	1986/87
A-Base	20,512	19,469	18,347	15,690	15,390
Energy R&D[a]	2,500	5,460	5,558	2,248	2,681
MDAs[b]	0	0	1,691	5,147	7,190
Frontier geoscience[b]	0	0	3,181	5,138	9,213
Northern oil and gas[b]	0	0	304	364	623
Asbestos[b]	0	0	296	470	307
Gaspé[b]	0	182	707	738	382
Boundary[b]	2,176	369	2,990	4,182	0
Total	25,278	25,480	33,075	33,977	35,787

Source: GSC, "Geological Survey of Canada Operating Resources, 1976-1992", Program Coordination and Planning, December 16, 1987.
[a] Renewable program.
[b] Sunset program.
Note: In 1988/89, Frontier Geoscience was transferred to the A-base budget of CANMET.

EMR Research Grants

EMR issues grants and contracts to industry and universities in geology, geophysics, exploration technology and remote sensing. The grant expenditures, in constant dollars, were presented in table 3.21. The level of support has stayed constant in current dollar terms and has declined by 22.5 percent in real terms since 1980.

Earth sciences receive an average of 47 percent of these total EMR grants; the remaining grants are allocated to energy research (29 percent) and to mining and minerals research (24 percent). The grants support applied research in universities and in institutes where funding may not be otherwise readily available. Earth science grant and contract expenditures are included in the totals shown for GSC in this section.

Table 8.21 Geological Survey of Canada Total Operating Resources by Program, Worst Case Scenario (1987/88 $ thousand)[a]

Year	A-Base	Energy R&D	MDAs	FGP[b]	NOGAP[c]	Asbestos[d]	Gaspé[e]	Boundary[f]	Total	Index 1987=100
1976-77	34,482	793	0	0	0	0	0	0	35,275	2.203
1977-78	35,954	731	0	0	0	0	0	0	36,685	2.031
1978-79	34,485	1,657	0	0	0	0	0	0	36,142	1.892
1979-80	31,496	1,061	0	0	0	0	0	0	32,557	1.725
1980-81	27,990	1,712	0	0	0	0	0	0	29,703	1.564
1981-82	29,433	1,148	0	0	0	0	0	0	30,581	1.381
1982-83	27,611	3,486	0	0	0	0	0	2,929	34,026	1.236
1983-84	27,968	7,843	0	0	0	0	262	530	36,603	1.256
1984-85	24,152	7,317	2,226	4,187	400	389	931	3,937	43,539	1.112
1985-86	20,541	2,943	6,739	6,726	476	615	967	5,475	44,482	1.068
1986-87	19,871	3,461	9,283	11,895	805	396	494	0	46,205	1.026
1987-88	18,568	3,158	10,306	10,479	896	0	590	0	43,997	1.000
1988-89	19,153	3,052	7,537	9,551	0	0	366	0	39,659	0.963
1989-90	18,548	2,989	2,506	9,180	0	0	0	0	33,223	0.925
1990-91	17,574	2,875	256	0	0	0	0	0	20,705	0.890
1991-92	17,124	2,761	0	0	0	0	0	0	19,885	0.855
1992-93	16,462	2,655	0	0	0	0	0	0	19,117	0.822

Source: GSC, "Geological Survey of Canada Operating Resources, 1976-1992", Program Coordination and Planning, December 16, 1987.

Note: These figures are presented in 1987 dollars. In 1981 dollars, A-base declines from $23.8 million to $12.7 million from 1976/77 to 1992/93. In current dollars, the change is $15.7 million to $20.0 million.

a 4 percent inflation per year assumed beyond 1987/88.

b Frontier Geoscience Program. In 1988/89, this program was transferred to the A-base budget of CANMET. If these funds are combined with A-base, from the program's inception in 1984/85, it gives a much different trend for A-base funding: $28.3 million; $27.3; $31.8; $29.1 for the years 1984/85 to 1987/88 respectively.

c Northern Oil and Gas Action Plan.

d A program focused on asbestos-producing regions of Québec.

e A program focused on the Gaspe.

f Two programs in support of boundary disputes with the United States and France.

Provincial Geoscience Activities

Table 8.22 shows a drop in some provinces expenditures resulting from the end of the old federal/provincial mineral subagreements which expired in the early 1980s. It also shows the increase in response to the first round of a 5-year Mineral Development Agreements (MDAs) which began to affect expenditures in 1985/86. In spite of a sharp drop in 1984/85, the increase over the 5-year period shown was just over 21 percent. Ontario and Quebec show considerable variation, but both finished the period with increases of 23 percent.

A different picture emerges when looking at A-base expenditures, which have declined over the period. Only in the Altantic provinces and the Northwest Territories did A-base geoscience expenditures rise. In conjunction with the fall in the A-base of the GSC, this indicates a decline in the capability of Canada's geological survey organizations to provide the data base necessary to support mineral exploration.

Table 8.22 Summary of Expenditures Reported by Provincial Geological Surveys, 1981/82 - 1985/86
(1981 $ thousand)

	1981/82	1982/83	1983/84	1984/85	1985/86
Newfoundland	3,586.5	2,281.9	1,874.0	3,076.4	3,905.5
PEI	0.0	0.0	3.6	1.7	18.5
Nova Scotia	1,782.0	2,351.7	2,203.7	2,219.5	2,882.9
New Brunswick	1,335.0	1,237.8	1,211.7	1,419.8	1,787.6
Quebec	9,179.5	11,568.7	16,482.9	9,750.8	11,320.3
Ontario	12,184.1	16,337.8	14,867.1	12,016.0	15,008.5
Manitoba	2,150.0	2,241.5	2,066.1	3,425.7	4,085.6
Saskatchewan	2,024.9	1,957.1	1,874.9	1,890.6	1,815.2
Alberta	6,667.7	6,475.4	6,189.3	5,717.7	6,158.7
British Columbia	2,962.4	2,545.5	2,082.8	2,285.1	3,581.9
Yukon	552.0	506.9	516.2	550.3	1,204.0
NWT	1,056.0	1,056.0	1,006.1	1,076.9	1,071.1
Total	43,480.1	48,560.3	50,378.5	43,430.5	52,839.9
Total A-base	38,265.9	41,152.3	42,716.9	36,572.5	36,909.5

Source: M. Wojciechowski, "R&D Funding Trends in the Earth Sciences in Canada", Report prepared for Canadian Geoscience Council, December 1988.

Looking at changes in total provincial expenditure by activity, table 8.23 shows major increases in geoscience data collection in 1983/84 and in mapping activities in 1984/85 and 1985/86.

Table 8.23 Summary of Provincial Geoscience Expenditures by Activity, 1981/82-1985/86
(1981 $ thousand)

	1981/82	1982/83	1983/84	1984/85	1985/86
Geoscience data collection	7,079.9	6,686.9	9,979.4	6,277.9	8,549.6
Mapping	10,547.9	8,601.8	8,136.9	10,322.7	13,106.0
Mineral deposit and commodity studies	6,217.5	7,489.9	6,245.2	6,813.6	8,099.5
Publications, analysis, information, inventories, services, administration	17,826.0	19,698.3	19,812.2	15,548.1	16,929.0
R&D activities & support	1,337.8	2,067.8	2,536.3	1,931.3	2,039.2
Other	471.0	4,015.7	3,668.5	2,536.8	4,116.6
Total	43,480.1	48,560.3	50,378.5	43,430.5	52,839.9

Source: M. Wojciechowski, "R&D Funding Trends in the Earth Sciences in Canada", Report prepared for Canadian Geoscience Council, December 1988.

Provincial Earth Science R&D Support

Quebec has a program of contract support for Geoscience R&D in companies and universities. It provides support for R&D projects in mineral exploration technology. In response to the CRS requests for information, Quebec reported funding support for geoscience R&D in universities ($18,000) and industry ($157,000) only for the 1980/81 fiscal year. In the CRS survey, Quebec was the only province to report in-house expenditures on R&D in geosciences, with expenditures of $72,000 and $200,000 in 1984/85 and 1985/86 respectively. Quebec also has a geotechnical research organization, le service de la géotechnique, which conducts in-house research and contracts out to universities.

The Ontario Geoscience Research Program (OGRP), introduced in 1978, offers financial support to Ontario universities for:

- defining and predicting significant mineral environments;
- providing geological information to assist the earth resources initiatives of the Ontario Geological Survey.

Support levels are shown in table 8.24.

Table 8.24 Ontario Earth Science Extramural R&D Support

	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87
OGRP	329.7	522.7	428.2	398.7	410.1	397.5
ETDP	546.4	953.7	1,455.5	761.0	739.6	0.0

The Exploration Technology Development Program (ETDP) provided funds for applied R&D by consultants and instrument manufacturers leading to the manufacture and marketing of innovative technology for mineral exploration. Funded by the Board of Industrial Leadership and Development (BILD), the program financed up to 60 percent of project costs, to a maximum of $150,000 per year for one project, for up to 3 years. Table 8.24 shows funding levels for this program.

RESEARCH IN AGRICULTURE

Federal Activities and Support

Federal research in agriculture is based in the Research Branch of Agriculture Canada the Research Program Service and 52 regional research establishments. The Research Branch has six institutes in the Ottawa region - the Animal Research Centre, the Biosystematics Research Institute, the Chemistry and Biology Research Institute, the Engineering and Statistical Research Institute, the Food Research Institute, and the Land Resource Research Institute. In addition, the Health of Animals Directorate of Agriculture Canada has nine laboratories, of which the Animal Diseases Research Institute is probably the most strongly oriented toward basic research. However, these laboratories are not included in Agriculture Canada's research budget in the public accounts. In addition to its in-house research activities, Agriculture Canada administers a large contract program for university researchers, and the part of the National Research Council of Canada's programs which are applicable to agriculture.

Agriculture Canada's S&T expenditures represented 25 percent of the department's total budgetary expenditures for 1985/86, with emphasis on 6 major projects:

- crop productivity and food research ($13.2 million)
- soil and water conservation ($16 million)
- disease and pest control ($18.2 million)

- animal productivity ($31.2 million)
- crop disease resistance and marketability ($73.2 million)
- oat and canola processing technology ($15.6 million)

Over 90 percent of Agriculture Canada's S&T budget is spent intramurally, and R&D accounts for over 85 percent of the total S&T expenditures, as shown in table 8.25. The increase over the eight year period shown was 52 percent.

University and industry R&D support from Agriculture Canada is very small, amounting to about 2 percent of the S&T budget for universities, and ranging from 1 to 5 percent for industry. Grants in aid of research to universities, part of the university support funding, were just over $1 million per year from 1981/82 to 1984/85.

The National Research Council also has some agricultural R&D involvement. It has a Plant Biotechnology Institute in Saskatoon, dedicated to research toward the improvement of economically important plants including oilseed crops, cereal grains, legumes and conifer trees through molecular genetics and plant cell technology. A Plant Biotechnology Fund provides money for non-government research. Laboratories in NRC's Division of Biological Sciences participate in a limited number of projects of agricultural importance involving vaccines for livestock and a diagnostic test for brucellosis. NRC's R&D expenditures on "Food and Forestry" are expected to decline by 18 percent from 1985/86 actual to 1987/88 estimates. This is in contrast to an increase of 130 percent in "Industrial Technology" in current dollar terms.[8]

Table 8.25 Agriculture Canada R&D Expenditures[a], 1980/81 - 1987/88 (1981 $ million)

	1980/81	81/82	82/83	83/84	84/85	85/86	86/87p	87/88p
R&D Expenditures	179.5	186.5	191.9	273.6	293.8	300.1	289.2	273.3
R&D as % of S%T expenditures	88	88	88	88	89	91	91	90

Source: Statistics Canada, 88-204.

[a] Canadian Forestry Service (CFS) R&D expenditures included from 1983/84 on. CFS R&D expenditures were $50.9 million, $57.4 million and $62.8 million in 1984/85, 1985/86 and 1986/87, respectively.

8. Government of Canada, Budget Estimates Part III, National Research Council, 1987/88.

Federal Provincial Agricultural Agreements

Subsidiary federal-provincial agreements for agriculture and food development administered under the Economic and Regional Development Agreements (ERDAs) have been signed by six provinces: Prince Edward Island, Nova Scotia, New Brunswick, Manitoba, Saskatchewan and British Columbia (see table 8.26). Alberta and Ontario have signed Memoranda of Understanding for subsidiary agreements. These agreements include funding for a substantial component of applied research in agriculture.

Table 8.26 Federal-Provincial Subsidiary Agreements for Agriculture and Food, Total and R&D Funding

	Duration	Total $ million	R&D $ million	Federal/Provincial Share %
P.E.I.	1984-89	41.0	6.0	100/0
Nova Scotia	1982-87	48.3	5.0	100/0
New Brunswick	1984-89	32.0	5.0	100/0
Manitoba	1984-89	38.3	32.5	58.5/41.5
Saskatchewan	1984-89	60.0	34.6	na
British Columbia	1985-90	40.0	7.0	50/50

Source: Government of Canada, Federal-Provincial Programs and Activities, 1985-1986, and CRS Survey.

Other Provincial Activities and Support

According to researchers at Agriculture Canada, as of 1987 "updated data on agricultural research expenditure by provincial governments, agri-business firms and private individuals after 1981 are not available at this time".[9] Only Ontario and Quebec have easily identifiable expenditure programs in agricultural research.

Ontario's Ministry of Agriculture and Food funds agricultural research through the Agricultural Research Institute of Ontario, an umbrella organization founded in 1962, which administers four colleges of

9. F.L. Tung and G. Strain, Canadian Farm Economics, vol. 21, no. 1, Ottawa: Agriculture Canada, Ottawa, 1987, p. 43.

agricultural technology, three horticultural stations, the Provincial Pesticide Residue Testing Laboratory, the Economics Branch of the Ministry, six experimental stations, the Horticultural Research Institute and the Ministry's contract agreement with the University of Guelph. Over half of the Institute's budget (see table 8.27) is covered by this contract agreement. Funding has shown a slight drop since 1981/82 in Ontario. The Ministry also supports clinical training in veterinary medicine.

Table 8.27 Budget of the Agricultural Research Institute of Ontario, 1980/81-1985/86
(1981 $ million)

1981-82	24.0
1982-83	24.4
1983-84	24.8
1984-85	25.6
1985-86	26.4
1986-87	26.7

Source: Ontario Ministry of Agriculture and Food, Report of the Agricultural Research Institute of Ontario.

Quebec's programs in agricultural research have more than doubled in real terms since 1980, as shown in table 8.28.

Table 8.28 Agriculture, Pêcheries et Alimentation Québec, Budget Appropriations for Research in Agriculture, 1980/81-1986/87
(1981 $ million)

	In-House Agricultural Research	Research Fund
1980-81	10.1	na
1981-82	9.8	na
1982-83	11.3	na
1983-84	11.7	na
1984-85	16.9	2.5
1985-86	17.9	3.0
1986-87	21.1	na

Source: Gouvernement du Québec, Budget Etimates, various years.

Agricultural research in the other provinces is not as clearly delineated. Nevertheless, it is clear that all provinces take an active and direct interest in agricultural R&D. Some specific programs are identified below.

In Alberta, a research division was established in 1983-84 in the Ministry of Agriculture. This division began a comprehensive review of agricultural research programs, technology transfer efforts and research needs in Alberta in 1985-86. The Ministry administers the Alberta Agriculture Research Fund which includes a program called Farming for the Future. Various other bodies support research, including the Alberta Agricultural Research Council which has a horticultural research centre at Brooks, and the Alberta Agricultural Research Trust.

The Manitoba Ministry of Agriculture contributes funding for research (for example, $875,500 in 1983-84) at the University of Manitoba. The three prairie provinces contribute grants to the Prairie Agricultural Machinery Institute (PAMI) which maintains stations at Humboldt Saskatchewan, Lethbridge Alberta, and Portage la Prairie Manitoba. This institute undertakes a considerable amount of development work as well as demonstration projects.

RESEARCH IN FORESTRY

Federal Activities

The Canadian Forestry Service (CFS), formerly part of the federal Ministry of the Environment but since 1983/84 under the Ministry of Agriculture, maintains six regional establishments. These centres conduct research into growth and diseases of tree species, insect pests, fungal and other diseases, hydrology, soil surveys and digital imaging. They also provide services such as environmental assessments, appraisal of pest damage, and chemical analyses, and they participate in the national forest statistics program. The Forest Products Laboratory in Vancouver and the Eastern Products Laboratory conduct research in process control, pulp and paper, and wood products. The Canadian Forestry Service also administers PRUF, the Program of Research by Universities in Forestry, which provided grants increasing from $1.2 million in 1981/82 to $1.9 million in 1984/85. CFS expenditures are shown in table 8.29. In 1986/87 research accounted for about one-third of its total expenditures.

The Forestry Research Advisory Council of Canada, a government-industry advisory body which produced its first report in August 1986, is in the process of developing a strategic plan for the research programs of the Canadian Forestry Service.

Table 8.29 Canadian Forestry Service Expenditures, 1980/81-1986/87 (1981 $ million)

	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87
Forest research and technical service	na	na	na	na	50.9	57.4	62.8
Forest development	na	na	na	na	77.0	79.9	90.7
Other	na	na	na	na	34.5	32.1	31.1
Total	53.5	55.7	136.3	171.3	162.3	169.4	184.6

Source: Government of Canada, Public Accounts, volume II, various years.

Federal/Provincial Forest Resource Development Agreements

Federal/Provincial Forest Resource Development Agreements have been signed with 8 provinces, as shown in table 8.30. Most of this funding is directed at forest management rather than research. For example, the plan for forestry research in Manitoba calls for an expenditure of $3.6 million (or 13 percent of the FRDA total) over the five-year period of the agreement for research on regeneration, forest nurseries, site classification, forest inventory, yield of managed stands, fire management, forest economics, tree improvement, insects and disease and the forest environment. A sub-plan for research, development and application under the Ontario agreement calls for the spending of $6 million (4 percent), of which the federal share is $4 million. Provisions for "extension, demonstration and R&D" in the British Columbia agreement amount to $27 million, or 9 percent of the total.

Table 8.30 Federal-Provincial Forest Resource Development Agreements

Province	Duration	Total $ million	Federal/ Provincial Share (%)
British Columbia	1985-90	300.0	50/50
Alberta	1984-89	23.0	50/50
Saskatchewan	1984-89	28.0	50/50
Manitoba	1984-89	27.2	50/50
Ontario	1984-89	150.0	50/50
Quebec	1985-90	150.0	50/50
New Brunswick	1984-89	77.4	55/45
Nova Scotia	1982-87	71.7	56/44

Source: Government of Canada, Federal Provincial Programs and Activities, 1985-86.

Other Provincial Forestry Research Activities

The British Columbia Forest Service has an extensive provincial research program in forestry, dedicated to harvesting, engineering, silviculture, protection, ecology, tree improvement, tree physiology, soil science and hydrology. The Service has two research stations and a research laboratory. The ecology and earth sciences program consumes nearly half of the research budget of about $8 million.

The Alberta Forest Service conducts a limited amount of research in cooperative genetics and tree improvement programs with Forest Management Agreement Holders in industry. A Forest Research Branch was established in 1982.

The Ontario Ministry of Natural Resources has a forest research station at Maple as well as field stations in Thunder Bay, Sault Ste. Marie, Midhurst and Dorset. Research focuses on silviculture and tree biology, tree breeding, and productivity.

Industry R&D Organizations

Forestry industry R&D statistics are given earlier in this chapter. Pulp and paper research is conducted principally by PAPRICAN (the Pulp and Paper Research Institute of Canada), which accounts for at least half of the R&D expenditures in this field. PAPRICAN is a joint venture of the federal government, McGill University, the University of British Columbia, and the Canadian Pulp and Paper Association. Founded in the 1920s, its operating budget was about $20 million in current dollars in 1985 and

1986, mostly contributed by member companies (87 percent in 1986 - see table 8.31). The federal government provides laboratory facilities at Pointe Claire in Quebec as well as some NRC and other grant support. The Department of Regional Industrial Expansion recently provided a grant of $15 million for construction of a laboratory in Vancouver which opened in April 1986. R&D projects in 1986 were aimed principally at improvements in productivity and product quality.

In January 1986, the University of British Columbia Pulp and Paper Centre at UBC was opened. Construction of the Centre was financed by the British Columbia government. UBC and McGill collaborate with PAPRICAN in providing postgraduate education and research in pulp and paper engineering. A new Pulp and Paper Centre was established in 1988 at the University of Toronto. It will encourage research and teaching and will receive $25,000 per year from each of six companies in the manufacturing and supply areas of the industry.

Table 8.31 Pulp and Paper Research Institute of Canada, Funding by Source, 1980-86
(1981 $ million)

Source	1980	1981	1982	1983	1984	1985	1986
Member assessments	10.7	11.1	11.5	9.6	12.1	13.0	14.3
Grants, NRC and other	0.8	0.7	0.6	0.8	0.7	1.1	0.4
Services	1.2	1.1	1.1	1.3	1.2	1.4	1.3
Other	0.7	0.6	0.5	0.3	0.3	0.6	0.5
Total	15.0	13.5	13.8	12.0	14.4	16.1	16.4

Source: PAPRICAN, Annual Report, various years.

CONCLUSION

Industry R&D support in all the resource sectors in Canada is below the national average of R&D intensity for all industry. This is the usual pattern for resource industries in most countries. Agriculture appears to be the least well supported by industry, with an R&D contribution in 1987 that was much lower (2.1 percent) relative to its GDP share of 5.7 percent than the other resource sectors, as shown in tables 8.32 and 8.33. Table 8.32 suggests that the mineral sector's relative contribution to R&D fell significantly over the 1980s, while its GDP share remained fairly constant, and much the same was true for forestry. The petroleum sector, not surprisingly, showed the biggest decline in terms of contributions to total industry R&D, from 15 percent in 1980 to 4 percent in 1987. This represented a real decline of 51 percent in terms of industry intramural R&D expenditures, as shown in table 8.33.

Table 8.32 Percentage Share of Total Industry R&D Expenditures and of Total GDP by Resource Sector, Selected Years

	1980		1983		1987	
	R&D	GDP	R&D	GDP	R&D	GDP
Minerals						
primary	1.8	2.2	1.7	1.7	1.2	2.2
processing	6.8	1.2	4.0	1.1	3.3	1.2
fabricating	1.4	1.2	1.5	0.9	1.3	1.0
Total	9.9	4.5	7.2	3.8	5.8	4.4
Petroleum						
primary	4.6	4.4	1.9	4.0	0.7	3.5
processing	10.3	0.2	7.1	0.3	3.2	0.2
Total	14.9	4.6	9.0	4.2	4.0	3.7
Agriculture						
primary and processing	3.1	6.2	2.9	6.3	2.1	5.7
Total	3.1	6.2	2.9	6.3	2.1	5.7
Forestry						
primary and processing	0.9	1.7	0.6	1.6	0.6	1.8
fabricating	3.3	2.0	2.2	1.8	2.0	1.8
Total	4.2	3.7	2.7	3.5	2.6	3.6
Total Resource Sector	32.1	19.1	21.6	17.7	14.5	17.4
Total All Industries	100.0	100.0	100.0	100.0	100.0	100.0

Source: tables 8.2 and 8.6.

Table 8.33 reinforces earlier evidence of the fact that the agricultural sector, for various historical, political and industry-organization reasons, receives a relatively high proportion of federal R&D support, whether measured against percent of sector sales, sector GDP, or industry contribution by sector. The high percent of "own source" funding for industry intramural R&D in agriculture (90 percent in 1986), reflects the fact that most of the government R&D support in this sector is for intramural R&D within the Department of Agriculture.

Table 8.33 Summary of Resource Sector R&D (or S&T) Support from Industry and Federal Sources, 1986 or 1987 (percent of total or real percent change)

		Industry Intramural R&D				Federal Support			
	Sector GDP Share %[a]	R&D % Share[b]	R&D as % of Sales[c]	R&D From Own Funds %[d]	Real R&D Change 1980-87 %[e]	R&D as % of Sector Sales[f]	Line Dept. S&T % of Total Federal[g]	R&D Real % Change[h]	NS & Eng. by Area of Application %[i]
Minerals	4.4	5.8	1.0[j]	80	6.4	0.12	9.6	38	6
Petroleum	3.7	4.0	0.5	95	-51.0	0.18			
Forestry	3.6	2.6	0.5	62	13.7	0.16	9.4	52	14
Agriculture	5.7	2.1	0.4	90	21.8	0.37			

Sources: [a] table 8.2, 1987.
[b] table 8.6, 1987.
[c] table 8.8, 1986.
[d] derived from table 8.9, 1986.
[e] table 8.5, 1980 - 1987.
[f] table 8.12.
[g] table 3.1.
[h] table 8.11, 1980/81 to 1987/88.
[i] derived from table 8.10, 1987/88.
[j] without Alcan, about 0.6 percent.

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APPENDIX A. BACKGROUND DATA

Table A.1 Value of Mineral Production of Canada, by Classes, Selected Years 1945-1985
($ million)

	Metals	Non-metals[a]	Structural Materials	Coal	Total[b]
1945	317	40	48	68	473
1950	617	95	132	110	954
1955	1,008	145	228	94	1,475
1960	1,407	198	323	75	2,001
1965	1,908	327	434	76	2,745
1970	3,073	481	450	86	4,090
1975	4,794	939	960	586	7,280
1976	5,073	1,162	1,103	607	7,946
1977	5,988	1,362	1,249	610	9,209
1978	5,698	1,478	1,508	779	9,463
1979	7,951	1,868	1,646	860	12,325
1980	9,697	2,532	1,669	932	14,830
1981	8,684	2,707	1,769	1,073	14,368
1982	6,874	1,979	1,730	1,294	12,093
1983	7,238	1,903	1,702	1,300	12,314
1984	8,670	2,366	1,951	1,795	14,782
1985	8,709	2,737	2,125	1,845	15,457
1986	8,798	2,522	2,342	1,726	15,410
1987	10,928	2,480	2,641	1,635	17,718

Source: 1945-83, Statistics Canada, Cataloques 26-201 and 26-202; 1984-87, Canadian Mining Journal, February, various years.

[a] Includes peat, for 1965-87

[b] Including "other minerals" for 1981-87, which are not shown elsewhere in the table.

Table A.2 GDP Implicit Price Deflator, Canada, 1975 - 1988
(1981 = 100)

1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
60.6	65.8	69.9	74.2	81.6	90.3	100.0	108.9	114.3	118.4	122.4	125.8	129.2	132.6[a]

Source: Bank of Canada Review.

[a] First Quarter, 1988.

Table A.3 Comparison of Canadian Price Indices, 1981 - 1987
(1981 = 100)

	1981	1982	1983	1984	1985	1986	1987
Consumer price index							
CPI total	100	110	117	122	127	132	138
CPI durable goods	100	105	110	113	117	123	127
CPI services	100	113	120	125	130	136	143
Raw materials price index							
Total excluding coal & oil and gas	100	97	99	103	100	104	109
Coal and oil and gas	100	120	129	131	137	87	94
Mineral raw materials price index							
Total	100	113	120	122	126	90	97
Excluding coal & oil and gas	100	93	97	98	95	98	107
Metallic materials							
Copper concentrates	100	88	92	81	87	90	106
Iron ore	100	104	105	110	114	116	111
Lead concentrates	100	71	58	73	57	68	106
Nickel concentrates	100	91	85	93	99	87	97
Other base metals, n.e.s.	100	91	95	105	95	97	104
Precious metals	100	83	99	85	77	88	99
Gold ingots	100	83	98	85	78	91	101
Silver	100	75	111	82	66	60	73
Platinum	100	77	100	88	74	119	139
Radioactive concentrates	100	110	99	95	92	91	89
Zinc concentrates	100	90	96	118	105	102	108
Nonmetal materials							
Asbestos	100	101	111	110	108	108	108
Other nonmetallic materials, n.e.s.	100	111	110	114	116	118	118
Sand and gravel	100	109	109	108	109	112	117
Silica sand	100	111	117	115	118	122	123
Stone	100	113	124	128	134	139	143
building	100	112	123	128	133	137	141
crushed	100	115	128	135	143	151	157
other	100	112	123	128	133	137	141
Sulphur	100	113	99	114	167	179	146
Mineral fuels							
Coal, thermal	100	110	111	119	120	119	120
Oil, crude	100	121	130	132	139	80	89
Natural gas	100	128	134	132	132	129	125

Source: CPI and Raw Materials PI, Bank of Canada Review, September 1988, pp. S128-9; Statistics Canada, 62-011.

Table A.4 Federal Government Expenditures by Program, 1980/81 - 1987/88
(1981 $ million)

	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88[a]
Agriculture	976.7	1,120.0	952.2	1,198.6	1,480.6	1,433.0	1,830.7	1,348.3
AECL	932.4	284.0	289.3	294.0	275.3	224.7	173.3	130.8
CIDA	739.8	803.0	856.7	952.8	1,125.8	1,036.8	1,511.1	1,627.7
Communications	147.3	175.0	458.2	210.0	239.0	214.9	214.6	215.9
EMR	3,495.0	1,082.0	2,386.6	2,627.3	3,486.5	1,820.3	1,217.8	549.5
Environment	594.7	678.0	750.2	666.7	636.8	572.7	605.7	595.2
Fisheries and Oceans	407.5	441.0	443.5	532.8	609.0	518.0	460.3	427.2
IDRC	46.5	47.0	54.2	58.6	68.4	70.3	79.5	82.0
MRC	90.8	100.0	103.8	122.5	132.6	131.5	133.5	133.1
National Defence	5,622.4	6,029.0	6,420.6	6,974.6	7,358.9	7,490.2	7,858.5	8,003.1
National Health and Welfare	17,386.5	17,768.0	17,876.0	19,609.8	20,909.8	21,404.4	21,949.1	22,604.5
NRC	241.4	272.0	309.5	346.5	395.3	340.7	328.3	315.8
NSERC	179.4	201.0	225.0	245.8	263.5	253.3	254.4	256.2
DRIE	691.0	528.0	859.5	899.4	903.7	866.0	926.1	890.9
SSHRC	46.5	47.0	51.4	52.5	53.2	51.5	55.6	52.6
Statistics Canada	152.8	222.0	165.3	166.2	175.7	170.8	239.3	164.9
Transport Canada	2,407.5	1,848.0	2,104.7	2,440.9	2,494.1	2,187.1	1,936.4	1,746.1
Others	34,919.2	35,830.0	37,572.1	40,129.5	43,886.0	45,498.4	45,040.5	46,104.5
Total	69,077.5	67,474.0	71,878.8	77,528.4	84,674.0	84,284.3	84,814.9	85,248.5

Source: Government of Canada, Public Accounts, Volume I, various years.
[a] Government of Canada, Budget Estimates, Volume II, 1987/88.

Table A.5 Federal Support for Science and Technology, 1980/81 - 1987/88
(1981 $ million)

	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87[p]	1987/88[p]
Agriculture	203.5	210.8	216.9	309.8	330.2	331.0	318.8	302.4
AECL	111.7	103.4	119.0	120.7	126.9	114.5	123.4	109.8
CIDA	40.6	41.9	44.6	42.0	41.9	42.6	43.7	54.6
Communications	74.9	89.9	94.9	75.4	79.4	63.6	52.4	39.2
EMR	215.1	232.2	235.6	252.6	285.4	316.9	311.4	308.7
Environment	303.8	309.3	317.1	276.3	288.8	284.1	306.4	304.7
Fisheries and Oceans	158.8	156.7	176.9	194.3	224.6	210.4	185.7	159.0
IDRC	44.1	45.9	49.2	55.7	63.9	66.8	72.7	75.5
MRC	91.0	100.4	104.2	123.1	132.6	132.0	133.8	133.2
National Defence	114.6	118.9	133.5	142.0	165.0	175.0	177.7	190.9
National Health and Welfare	80.3	86.5	86.4	96.2	99.9	93.7	98.7	102.2
NRC	254.7	285.5	323.6	360.0	409.2	346.3	369.2	347.8
NSERC	180.7	202.1	225.3	246.8	264.1	254.3	254.9	256.7
DRIE	111.6	138.0	119.3	143.4	146.1	165.7	175.7	178.2
SSHRC	47.4	46.9	52.2	52.9	53.4	52.0	56.1	53.2
Statistics Canada	174.6	246.9	191.2	201.0	210.5	214.6	278.1	210.8
Transport Canada	19.3	23.5	25.3	33.8	37.5	30.6	31.2	29.9
Others	285.3	306.8	316.4	331.2	322.9	325.4	339.7	347.4
Total	2,512.1	2,745.6	2,831.6	3,057.2	3,282.3	3,219.5	3,329.7	3,204.3

Source: Statistics Canada, 88-204.

Table A.6 Value of Mineral Production, by Province, By Commodity, 1985
(in 000's of $'s)

	Nfld.	P.E.I.	N.S.	N.B.	Quebec	Ontario	Manitoba	Sask.	Alberta	B.C.	Yukon	N.W.T.	Canada
Metals													
Antimony				2,344						4,233			6,577
Bismuth				3,641		26	7			592	10	68	4,344
Cadmium				266	423	3,169	586	28		872	9	758	6,111
Cobalt						79,599	12,128						91,727
Columbium					x								x
Copper				13,031	136,265	554,169	133,986	9,299		598,607			1,445,357
Gold				3,506	407,665	440,596	29,231	2,649	117	89,604	43,098		1,197,051
Iron Ore	835,633				x	x				3,185			1,545,783
Iron, remelt					x								x
Lead				42,362		2,437	394			61,429	877	44,805	152,304
Molybdenum					2,301					73,089			75,390
Nickel						968,358	266,603						1,234,961
Platinum group						x	x						x
Selenium					3,148	2,263	973	172					6,556
Silver				52,215	13,836	136,487	9,724	1,325		101,485	12,675	9,615	337,362
Tantalum							3,045						3,045
Tellurium					304	121	100	18					543
Tin										1,795			1,795
Tungsten				x								x	x
Uranium							519,479			438,181			957,660
Zinc	37,642			292,875	81,571	341,722	80,356	5,253		135,441	41	341,923	1,316,824
Total Metals	873,275			410,240	1,288,313	3,275,941	537,133	456,925	117	1,070,332	56,710	577,754	8,546,740

Table A.6 Value of Mineral Production, By Province, By Commodity, 1985 (continued)
(in 000's of $'s)

	Nfld.	P.E.I.	N.S.	N.B.	Quebec	Ontario	Manitoba	Sask.	Alberta	B.C.	Yukon	N.W.T.	Canada
Nonmetals													
Asbestos	20,442				241,054					90,779			852,275
Barite	362		1,779			1,500				2,694			6,335
Gemstones					110					1,041			1,151
Gypsum	5,337		52,216			15,823	2,605			4,340			80,321
Magnesitic dolomite & barite					6,875					3,616			10,491
Nepheline Syenite						18,903							18,903
Peat	49	685	920	13,154	18,488	612	12,494	1,750	10,164	159			58,475
Potash				x				x					642,054
Quartz	1,853		x	x	x	11,930	2,959	x	4,700	2,013			44,110
Salt			x	x	x	136,604		26,817	16,218				225,995
Soapstone, talc, pyrophyllite					3,007	9,181							13,683
Sodium Sulphate								29,905	3,482				33,387
Sulphur, in smelter gas				11,630	12,035	35,948	42			2,199	88	3,960	65,902
Sulphur elemental						82		636	851,763	29,174			881,655
Total Nonmetals	29,538	685	86,410	59,925	310,241	230,693	18,100	672,755	886,327	136,015	88	3,960	2,434,737

Table A.6 Value of Mineral Production, By Province, By Commidity, 1984 (continued)
(in 000's of $'s)

	Nfld.	P.E.I.	N.S.	N.B.	Quebec	Ontario	Manitoba	Sask.	Alberta	B.C.	Yukon	N.W.T.	Canada
Coal			169,000	29,800				125,100	485,500	1,101,700			1,884,100
Structural Materials													
Clay products	1,150		7,750	4,325	21,987	91,725	2,150	4,050	7,550	3,800			144,487
Cement	8,462		22,094	15,134	196,200	292,225	33,148	16,769	118,779	77,239			780,050
Lime				5,340	18,258	90,115	5,725		10,305	7,300			137,043
Sand and gravel	11,350	1,550	21,300	9,700	60,019	167,400	33,150	26,375	109,000	76,835	1,225	33,350	551,254
Stone	3,335		21,250	11,120	142,574	151,887	8,635		2,324	36,325		795	378,155
Total Structural Materials	24,297	1,550	72,394	45,619	439,038	793,352	82,808	47,194	247,958	201,409	1,225	34,145	1,990,989
Total Other Minerals			4,507	199,249	176,071	9,068	2,320	480		1,016		33,478	426,189
Grand Total	927,110	2,235	327,804	550,091	2,236,841	4,476,057	647,109	1,304,294	1,593,382	2,510,472	58,023	649,337	15,282,755

Source: Canadian Mining Journal, February 1986.

Table A.7 Canada, Indexes of Gross Domestic Product by Industry (1971 = 100)

Industry or Industry Group	1984 Average	1985 Average	Percentage Change
Gross domestic product	150.0	156.4	4.2
Primary industries			
Agriculture	115.0	117.2	1.9
Forestry	125.4	124.6	-0.6
Fishing and trapping	109.4	112.3	2.7
Mines, quarries and oil wells	110.7	112.1	1.3
Metal mines	81.0	79.0	-2.5
Placer and gold quartz mines	107.9	121.6	12.7
Iron mines	59.0	60.7	2.8
Other metal mines	85.4	81.6	-4.5
Mineral fuels	128.5	132.5	3.1
Coal mines	329.3	347.5	5.5
Crude Petroleum and Natural Gas	113.4	116.3	2.6
Nonmetal mines	116.0	105.1	-9.4
Asbestos mines	38.8	39.1	0.7
Secondary Industries			
Manufacturing	138.8	145.2	4.6
Nondurable manufacturing	137.2	141.6	3.2
Petroleum and coal products industries	86.4	84.8	-1.9
Durable manufacturing	140.3	148.6	5.9
Primary metal industries	122.7	124.6	1.5
Iron and steel mills	122.6	124.3	1.4
Steel pipe and tube mills	101.5	106.9	5.2
Iron foundries	111.7	111.0	-0.7
Smelting and refining	119.6	122.2	2.2
Nonmetallic mineral products industries	111.9	119.5	6.8
Cement manufacturers	97.6	108.4	11.1
Ready-mix Concrete manufacturers	98.6	105.4	6.8
Construction industry	106.1	112.3	5.5
Transportation, storage, communication	178.6	185.5	3.9
Electric power, gas and water utilities	200.7	211.2	5.2
Trade	166.5	177.9	6.8
Finance, insurance, real estate	176.0	185.2	5.3
Community, business and personal service	154.2	159.7	3.6
Public administration and defence	140.7	141.8	0.8

Source: EMR, The Canadian Mineral Industry Monthly Report, February 1986, table 1.

Table A.8 Foreign Control in the Resource Sector, 1982 and 1983

	Agriculture, Forestry Fishing and Trapping		Mines, Quarries and Oil Wells	
	1982	1983[p]	1982	1983[p]
	(number)			
Corporations				
Canadian control				
Private sector	21,511	21,716	6,014	6,276
Government	3	4	24	23
Foreign control	111	101	485	440
Total corporations	21,625	21,821	6,523	6,739
	($ million)			
Assets				
Canadian control				
Private sector	x	x	61,134	63,713
Government	x	x	4,866	4,666
Foreign control	455	394	33,902	37,383
Total corporations	10,752	11,130	99,902	105,761
Equity				
Canadian control				
Private sector	x	x	25,397	26,230
Government	x	x	1,884	1,661
Foreign control	142	128	15,720	17,906
Total corporations	3,365	3,504	43,001	45,797
Sales				
Canadian control				
Private sector	x	x	18,145	18,260
Government	x	x	1,025	917
Foreign control	325	275	18,706	20,654
Total corporations	8,222	8,575	37,877	39,831
Profits				
Canadian control				
Private sector	x	x	1,762	1,341
Government	x	x	-3	-31
Foreign control	27	14	4,528	6,503
Total corporations	449	359	6,287	7,813

Note: figures may not add to totals due to rounding.

APPENDIX B. Responses to CRS Survey of University Mining and Metallurgy Departments

Table B.1 R&D in Engineering Departments
Funding by NSERC, 1980-1986 (Current Dollars)

University and Program	1980	1981	1982	1983	1984	1985	1986
Alberta mineral	93,893	225,474	102,873	136,702	156,051	154,912	125,578
McMaster met./mat.	284,435	584,798	406,537	584,112	1,207,140	1,040,541	1,055,693
McGill min./met.	na	na	na	na	1,308,837	1,128,894	1,546,479
Laval min./met.	230,462	193,000	126,555	377,646	434,157	563,043	570,402
Ecole Poly. metall.	216,438	419,915	565,447	465,059	479,690	744,757	1,291,143
mineral	170,043	124,670	145,566	119,780	146,715	180,715	228,028
Toronto metall.	611,762	1,122,645	548,660	1,055,193	1,059,845	1,184,853	1,077,731
Queen's metall.	na	141,934	155,834	187,785	371,734	426,974	347,948
mining	na	12,693	59,223	65,845	141,152	86,111	59,823
Total	na	na	na	na	5,305,321	5,510,800	6,302,825

Source: CRS survey of universities.

Table B.2 R&D in Engineering Departments
Funding from Other Federal Sources, 1980-1986 (Current Dollars)

University and Program	1980	1981	1982	1983	1984	1985	1986
Alberta							
mineral	35,093	138,159	8,819	310,980	17,857	292,246	242,819
McMaster							
met./mat.	190,539	274,902	404,586	453,956	576,166	457,288	717,392
McGill							
min./met.	na	na	na	na	649,306	294,913	569,459
Laval							
min./met.	196,169	74,524	74,835	88,096	159,448	101,927	126,454
Ecole Poly.							
metall.	na	0	103,718	129,173	108,519	137,836	171,335
mineral	na	na	37,500	35,800	46,985	43,554	33,661
Toronto							
metall.	140,000	148,126	106,591	70,000	33,887	25,021	38,115
Queen's							
metall.	na	183,283	210,122	156,435	197,767	45,697	144,348
mining	na	96,800	60,000	68,897	107,480	129,540	91,923
Total	na	na	na	na	1,897,415	1,528,022	2,135,506

Source: CRS survey of universities.

Table B.3 R&D in Engineering Departments
Funding by Provincial Governments, 1980-1986 (Current Dollars)

University and Program	1980	1981	1982	1983	1984	1985	1986
Alberta mineral	386,048	192,381	145,724	560,177	247,520	268,581	462,421
McMaster met./mat.	0	0	256,050	233,474	0	0	69,483
McGill min./met.	na	na	na	na	154,217	229,006	125,352
Laval min./met.	44,420	171,971	114,990	172,180	277,131	535,540	462,584
Ecole Poly. metall.	na	82,675	112,066	97,605	205,219	337,604	420,465
mineral	na	na	179,516	298,530	661,099	731,545	614,266
Toronto metall.	0	76,400	162,800	0	0	0	0
Queen's metall.	na	2,530	45,730	54,860	11,116	17,644	6,693
mining	na	11,640	65,800	23,359	0	68,115	39,800
Total	na	na	na	na	1,556,302	2,188,035	2,201,064

Source: CRS survey of universities.

Table B.4 R&D in Engineering Departments
Funding by Industry, 1980-1986 (Current Dollars)

University and Program	1980	1981	1982	1983	1984	1985	1986
Alberta							
mineral	130,088	350,833	275,910	492,073	351,747	178,326	16,341
McMaster							
met./mat.	66,581	60,892	168,237	209,138	144,087	158,095	268,476
McGill							
min./met.	na	na	na	na	82,850	355,611	401,808
Laval							
min./met.	7,800	50,200	29,468	15,685	18,500	72,000	110,945
Ecole Poly.							
metall.	na	31,400	46,017	29,725	75,617	110,147	243,159
mineral	na	na	34,944	61,500	59,152	26,426	164,279
Toronto							
metall.	115,877	234,112	301,033	276,783	306,090	247,933	263,873
Queen's							
metall.	na	0	110,000	0	13,000	93,326	159,575
mining	na	110,990	35,750	43,690	113,136	47,913	71,251
Total	na	na	na	na	1,164,179	1,289,777	1,699,707

Source: CRS survey of universities.

Table B.5 R&D in Engineering Departments
Other Sources of Funding, 1980-1986 (Current Dollars)

University and Program	1980	1981	1982	1983	1984	1985	1986
Alberta							
mineral	6,063	8,427	72,818	7,585	1,365	5,275	16,517
McMaster							
met./mat.	0	59,869	92,334	139,908	231,889	119,474	0
McGill							
min./met.	na	na	na	na	11,638	46,110	25,033
Laval							
min./met.	24,000	17,850	40,672	24,716	8,000	17,500	17,000
Ecole Poly.							
metall.	na	77,967	125,689	18,608	36,152	5,169	49,606
mineral	na	na	30,796	12,000	0	39,490	0
Toronto							
metall.	136,184	167,307	11,566	17,775	137,842	262,261	136,534
Queen's							
metall.	na	118,500	0	0	28,000	0	12,846
mining	na	0	0	0	0	0	0
Total	na	na	na	na	454,886	495,279	257,536

Source: CRS survey of universities.

Table B.6 R&D in Engineering Departments
Total Funding, 1980-1986 (Current Dollars)

University and Program	1980	1981	1982	1983	1984	1985	1986
Alberta							
mineral	651,185	915,274	606,144	1,507,517	774,540	899,340	863,676
McMaster							
met./mat.	541,555	980,461	1,327,744	1,620,588	2,159,282	1,775,398	2,111,044
McGill							
min./met.	na	na	na	na	2,206,848	2,054,534	2,668,131
Laval							
min./met.	502,851	507,545	386,520	678,323	897,236	1,290,010	1,287,385
Ecole Poly.							
metall.	439,654	611,957	952,937	740,170	905,197	1,335,513	2,175,708
mineral	997,570	924,093	428,322	527,610	913,951	1,021,730	1,040,234
Toronto							
metall.	1003823	1,748,590	1,130,650	1,419,751	1,537,664	1,720,068	1,516,253
Queen's							
metall.	na	446,247	521,686	399,080	621,617	583,641	671,410
mining	na	232,123	220,773	201,791	361,768	331,679	262,797
Total	na	na	na	na	10378103	11011913	12596638

Source: CRS survey of universities.